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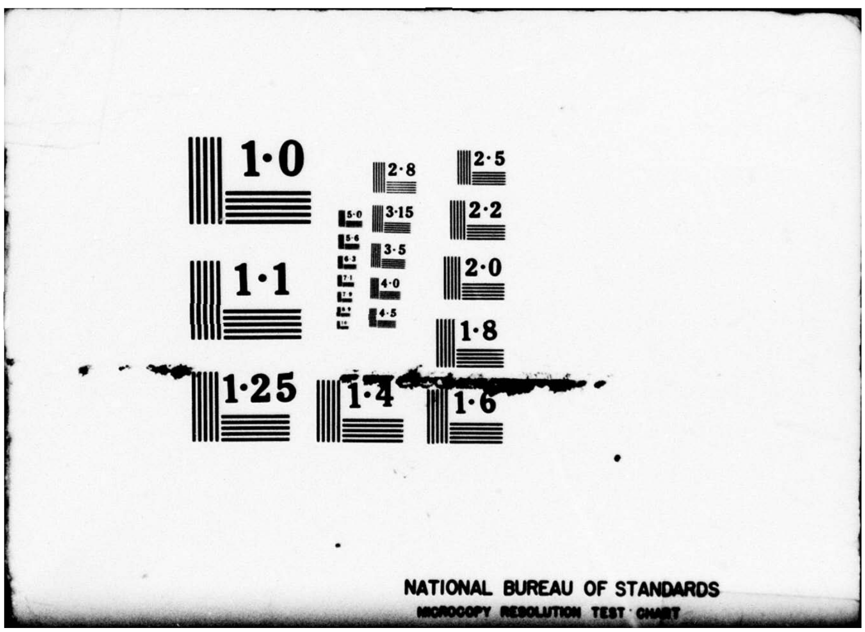
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DIRECTOR NOTES

A recent visit to the U.S. Army Materials and Mechanics Research Center (AMMRC) reminded me that we do not often enough emphasize the importance of materials related research to our shock and vibration technology. AMMRC's Mechanics Research Laboratory, under the leadership of Richard Shea, conducts research in materials and solid mechanics which yields information vital to the effective design of structures to withstand increasingly severe environments at high reliability levels. The results of their research have made significant contributions to systems development efforts.

Current programs at AMMRC in shock impact mechanics are pushing the state-of-the-art. For example, they're attempting to develop a better understanding of dynamic failure criteria beyond the wave propagation stage into the failure mode. Significant work is also being done in the areas of fragmentation and penetration mechanics.

AMMRC's work on applications of new materials provides another major thrust. They are assisting in the preparation of a DoD/NASA Design Guide in Advanced Composites. They have been instrumental in the application of high-strength, thermal-shock-resistance ceramics to engines. Applications of composites in the design of portable bridging systems are expected to result in significant weight reduction with increased rigidity. Programs are under way for the development of applications for the new metal-matrix composites. My visit to AMMRC was profitable and interesting. I consider their laboratory to be a vital part of our defense team.

H.C.P.

EDITORS RATTLE SPACE

BOOK REVIEWS*

It would be interesting to know how engineers select the various types of books - reference, theory, practice, or special techniques. Furthermore I wonder how many people have thought about it. Short of examination in a book store or by trial, books are selected from references, advertisements, recommendation of others, and book reviews. It appears to me that of all these means, selection on the basis of a book review is last -- yet when properly written it could be the most effective means.

The purpose of the DIGEST book review is to help the reader select the right book for the right purpose. What should be contained in a book review? The book review should reveal content and effectiveness of presentation. A book can contain good material, but if it is poorly written or illustrated, it will not provide an effective means of communication.

To be more specific a good book review should contain some background information on the author such as philosophy and motivation for writing (a college course, industrial practice manual, new techniques, or handbook material). A good concise description of the content and how effective it is presented through writing style and illustration is essential. Of course technical accuracy is implied, however, comments on degree of precision are valuable. Some statements on who would profit by its use and the slant of the presentation are necessary.

I believe cost should be mentioned; however, it should have little bearing on the selection process. The value of information contained in most books is for greater than the cost of the book. Only books that mislead or contain errors are not worth the cost. Fortunately I have seen or read about few of these books since 1969.

R.L.E.

*This is the third of a series of editorials on the purpose of the various sections of the DIGEST

SYSTEM RELIABILITY ASSESSMENTS USING CRITICAL EXCITATIONS

R.F. Drenick and P.C. Wang*

Abstract - Critical and certain related excitations are applied to mechanical and structural reliability problems involving the assessment of the resistance of systems to dynamic loads whose characteristics are partly or largely unknown. The experience gained thus far in practical situations and possible extensions of the use of the technique are described. Dependable, but somewhat conservative, reliability assessments have been achieved that might be applicable to various systems.

A recurrent problem in many fields of engineering is that of assessing whether or not a system that has been designed to survive, perhaps with some tolerable level of damage, any of a large class of possible excitations can indeed survive. This problem arises in civil engineering with regard to the effects of earthquakes, wind forces, and wave motion; in aeronautical engineering with regard to the effects of wind gusts and air or jet turbulence; and in mechanical engineering in the study of engine vibrations and vibration effects on delicate instruments. The common factors in all cases are 1) the uncertain nature of the characteristics of the excitations to which the system might be subjected, and 2) the probabilities with which such excitations are likely to occur. These factors are of greatest significance in systems of great economic, social, or military value. In such cases, any statement regarding system integrity should be made with a high level of confidence and ought to be compared only with information known to be at a comparable level of confidence. Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].

Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that the concept has considerable theoretical and practical potential. It is therefore of interest to report on the work thus far in this area and on some possible extensions.

The technique is based on the assumption that it is possible to characterize, at a desired level of confidence, a certain class of excitations that a system should be able to withstand. The critical excitations within that class are used to drive the dynamical variables of the system to their highest response peaks. If those peaks are compatible with the damage level that can be tolerated in the system, the design is judged satisfactory.

The intuitive appeal of the technique lies in the fact that only reliable data regarding excitations of concern are used. In practical applications, however, problems are often encountered. It is frequently difficult to define the class of excitations that the system should be able to withstand. Design engineers usually have fairly definite notions of the excitations they consider realistic or credible and what their designs should be prepared to accommodate. It is another matter, however, to convert design concepts into mathematically manageable definitions. The compromise has been to define so-called subcritical excitations of a system.

Subcritical excitations have for the most part applied to earthquake engineering. This review describes both critical and subcritical excitations and some of the results that have been obtained in earthquake engineering. Partially solved and potential problems are surveyed.

The general conclusion is that the use of critical and subcritical excitations results in realistic, if somewhat conservative, reliability assessments, but that they can be used with greater assurance than those derived from others now in use or under consideration. The technique might eventually be used, either in its present or in some modified form, with systems whose survival and integrity is of considerable importance.

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CRITICAL EXCITATIONS

In order to derive the critical excitations of a system, information available regarding the system under consideration must be collected, including the excitations the system should be capable of withstanding; the reliability of the information must also be established. The various structures studied thus far in earthquake engineering have included some already built, some in the process of design, and one after it collapsed. The analyses were based on the assumption that the equations of motion, established from engineering drawings and restricted to the elastic domain, did in fact adequately describe the structure. In other words, no allowances were made for uncertainties regarding system dynamics.

With regard to the excitations, it was initially assumed that only an upper bound on the intensities of the ground motions was known at the desired level of confidence. The idea was that a designer of a structure in, say, San Diego would be able to establish that earthquakes with intensities beyond a certain level could not be disregarded in his design. It was further assumed that he could establish this level with confidence because pertinent statistics are sufficiently reliable, and it was also assumed that no other ground motion statistics are reliable enough to be utilized. A class of admissible excitations was thus defined.

It was necessary to determine the critical excitations of the structure in that class. The critical excitations have intensities not exceeding an assumed maximum, and they drive selected structural variables to their highest response peaks. Such excitations are not very difficult to determine. The precise form of an excitation depends on the definition of its intensity. Table 1 shows three examples [3]. The symbol δ denotes the unit impulse and h the impulse response function of the variable under consideration. The first example shows a critical excitation that is, except for a constant factor, the time-reversed impulse response. The second example is a squared-off version of the first. (In undamped systems, this version is a combination of sine waves, as is sometimes expected.)

One disadvantage of examples such as those shown is that they can lead to preposterously large response peaks, especially for structures with relatively large fundamental periods. That is, the response induced in the structure by one of its critical excitations would be larger than could occur as a result of any realistic ground motion. Information regarding ground motions other than their intensity also lead to disqualification. Unfortunately, critical excitations derived without the benefit of information regarding ground motions are often disqualified.

Table 1. Examples of Critical Excitations

Intensity Definition (I)	Critical Excitation	Response Peak	Notation
$\left[\int_0^\infty x^2(t)dt\right]^{1/2}$	$(I/N)h(-t)$	IN	$N^2=\int_0^\infty h^2(t)dt<\infty$
$\max_t\lvert x(t)\rvert$	$Ih(-t)/\lvert h(-t)\rvert$	IN_1	$N_1=\int_0^\infty \lvert h(t)\rvert dt<\infty$
$\int_0^\infty \lvert x(t)\rvert dt$	$I\delta(t+t_m)$	IN_2	$N_2=\max_t\lvert h(t)\rvert = \lvert h(t_m)\rvert<\infty$

It has not yet been possible to establish unequivocally the additional information required and how to utilize it to determine critical excitations in earthquake engineering. A variation of the basic idea that has been somewhat successful is described in the next section.

SUBCRITICAL EXCITATIONS

Subcritical excitations are derived from critical ones. Although the characteristics of realistic ground motions have not been established, motions that have already been recorded are real -- although some might be more typical than others for a particular geographical site or geological environment. It might be surmised that any linear combination of recorded ground motions could be considered realistic, pro-

vided the intensity does not exceed the maximum assumed for a given location. These linear combinations thus define a manifold of all possible excitations. Consider those excitations that *lie within* this manifold -- and hence are realistic -- but differ least from the critical ones described above to be the subcritical excitations of the structure. (The least difference is taken as the least squares.)

RELIABILITY ASSESSMENTS

The earthquake resistance of various structures has been assessed by using many of their subcritical excitations. Twelve ground motion records, obtained in California during the past 40 years, were used as basis excitations to establish linear manifolds. All were recorded within 30 km from epicenters.

Some of these assessments are shown in Table 2. They are typical of others [6-8]. All have been normalized to the intensity of the ground motion of the NS component of the Imperial Valley earthquake, as recorded at El Centro on May 18, 1940. The subcritical excitations were derived from the critical ones shown in Table 1. The structural analyses were executed with modified versions of the STRUDL [9] and XTABS programs [10].

The response peaks listed in Table are from 2.5 to *3.5 times greater than those calculated for the* El Centro ground motion. This implies that some realistic excitations -- namely, subcritical ones -- have the same intensity as the El Centro ground motion but induce response peaks in the structures that are higher by the factors cited. One such excitation, shown in Figure 1, drives the top floor of Office Building 1 (Table 2) to its highest peak. (Other peaks for the same building are similar.) On inspection, the excitation can pass for a realistic ground motion in the sense that no conspicuous traits distinguish it from recorded motions. (Nor does a Fourier amplitude spectrum reveal such traits.)

It is of interest whether or not the structures were designed with a ductility margin sufficient to absorb the motion described by the large peaks (see Table 2). The two office buildings are considered satisfactory. (Both were in fact designed by a consulting firm with broad experience in earthquake engineering.) The Laboratory Building and the Hospital are judged to fall short of what might be desired. In the case of the Laboratory Building, the same conclusion was independently reached by its owners, and a reinforcement program is underway. The collapse of the Hospital during the San Fernando earthquake of February 9, 1971, confirms the conclusion for this building.

Table 2. Reliability Assessments

	Response-Peaks		*Ductility Ratios*	
	Due to El Centro	Due to Sub-critical Excita-*tions*	Due to El Centro	Due to Sub-critical Excita-*tions*
Office Building 1				
Top floor displ. (ft)	1.36	3.41		
Col. moment (ft-k)	972	2785	1.09	2.50
Col. axial force (k)	952	2500		
Laboratory Building				
Top floor displ. (ft)	0.53	1.87		
Col. moment (ft-k)	1021	3334	1.83	4.98
Col. axial force (k)	369	1144		
Office Building 2				
Top floor displ. (ft)	0.46	1.20		
Col. moment (ft-k)	721	1123	0.84	1.34
Col. axial force (k)	*1096*	*2073*		
Hospital				
2nd floor displ. (ft)	0.218	0.307		
Ext. Col.				
Moment (ft-k)	1922	2680		
Shear (k)	307	428	≅12	≅18

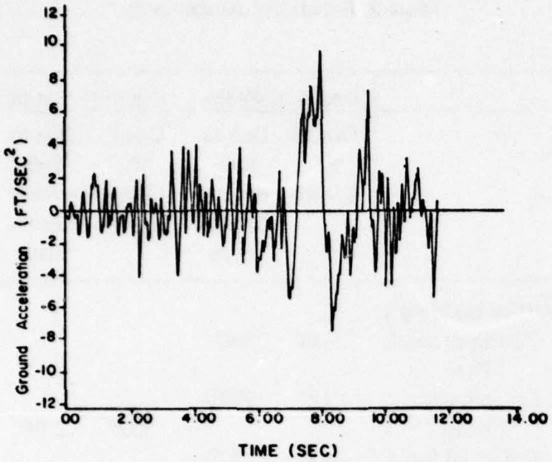

Figure 1. Example of a Subcritical Excitation with El Centro Intensity

DISCUSSION AND CRITIQUE

The results reported above, and others not reported in this review, support the conclusion that reliable, though somewhat conservative, assessments of structural earthquake resistance are possible by the method described. There is every reason to believe that similar assessments can be expected in other fields. These remarks should not be interpreted, however, to mean that modifications in the present method or variations on the original idea are not worthwhile. On the contrary, improvements and extensions are desirable in several directions.

First, the transition from a critical to a subcritical excitation contributes to the realism of the method, but at a price: the neat extremal properties of the critical excitation are lost. There is no guarantee that a subcritical excitation generates the highest response peak among all of those in the manifold of realistic ones. Computations have shown excitations that lie in the manifold but produce somewhat higher response peaks than the subcritical ones. This is not desirable. It would be better to determine the critical excitation in the manifold, but, although it can be done, no computational experience yet exists.

It would be even better to have a clear definition of what constitutes a realistic excitation. In earthquake engineering, several studies have been published [4, 5], but none has been practically applied. Success in this direction might eliminate a further disadvantage of assessments based on subcritical excitation: the sensitivity to the choice of the basis excitations. The elimination and/or addition of one such excitation can apparently bring about a non-negligible change in the response peaks that can be generated by the subcritical excitation. This is not desirable.

The nature of the geological overburden is an important factor in the assessment of earthquake resistance. Perhaps its importance would decrease if assessments were made using the critical excitations of a structure.

The computations in all case studies thus far have been comparable, perhaps slightly less than, those required for the reliability assessment of dynamical systems by other methods. Possible computational shortcuts are now being explored in an effort to economize, and additional study is desirable.

Evidently any mechanical system becomes nonlinear as it approaches failure. It is therefore desirable to extend the method to nonlinear systems. One theoretical extension has thus far been made [11], but no appreciable computation has been done. It is thus not clear that this particular extension will be suited to practical applications.

ACKNOWLEDGMENT

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LITERATURE REVIEW

survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains reviews of the literature on seismic waves and circular saw vibration research. The second part of a four part article by S. De on surface waves and guided waves in the earth's crust, mantle, and ocean is given.

An interesting article on circular saw vibration research by C.D. Mote, Jr. and R. Szymani deals with fundamental research and long term implications.

ON SEISMIC WAVES
PART II: SURFACE WAVES AND GUIDED WAVES

S. De*

Abstract - In theory, many types of surface and guided waves can exist in the earth. They include

- *Rayleigh waves in the continetnal and oceanic crust*
- *Rayleigh waves in the mantle*
- *Love waves in the continental and oceanic crust*
- *G waves in the mantle*
- *Lg and Rg waves*
- *Sofar waves and T phases in the ocean*
- *Surface waves generated by explosion*
- *Fundamental modes of vibration and low order overtones on earth*

Several of these wave types are described in this second part of the article.

General Features of Rayleigh Waves. Elastic surface waves were first investigated by Lord Rayleigh [1], who showed that their effects decrease rapidly with depth in a channel or otherwise bounded system, usually as an exponential function, and that their propagation velocity is smaller than that of body waves. The free surface of a half-space or sphere forms the upper boundary of the system, and an elastic discontinuity -- similar to that at the bottom of the earth's crust -- forms the lower boundary. The propagation velocity of such waves is independent of frequency and depends only on the elastic constants of the material. Thus no dispersion occurs, and a plane surface wave will travel without changing form.

At a depth of about 0.193 wavelength lies a plane in which no motion occurs parallel to the surface. At greater depths the amplitude once again becomes finite. Because its sign is opposite the sign at the surface, vibrations are opposite in phase. Rayleigh waves have been described in many textbooks [2 - 6].

A high-frequency Rayleigh wave attenuates more rapidly with depth than a low-frequency wave. The equation for Rayleigh waves is

$$S_R^3 - 8\,S_R^2 + (24 - 16\,P_S)\,S_R - 16(1 - P_S) = 0$$

where

$$S_R = V_R^2/V_S^2 \text{ and } P_S = V_S^2/V_P^2$$

In the equations V_P equals compressional-wave velocity, V_S is shear-wave velocity, and V_R indicates the velocity of the Rayleigh waves.

The motion of a surface particle is elliptic and retrograde during the passage of a Rayleigh wave. The major axis is vertical, and the amplitude of displacement in the direction of propagation is about 3/2 that in the horizontal direction.

Lamb [7] showed that a disturbed free surface of a semi-infinite elastic solid generates relatively weak dilatational and shear pulses and a strong Rayleigh pulse. Stoneley [8, 9] and others have shown that Rayleigh waves can exist if the boundary is not free and if the medium is nonhomogeneous. Such waves that travel along the boundary between two thick media are called Stoneley waves. Their motion can be either retrograde or direct depending on the medium through which the wave is viewed. Sezawa and Kanai [10] have shown that the motion can be direct on a free surface in certain cases.

The simple theory of Rayleigh and Stoneley waves fails except for very short wavelength because of layering. Scholte [11] has discussed the range and existence of Rayleigh and Stoneley waves.

The symmetrical (M_1) and antisymmetrical (M_2) vibrations of a free plate were first described in 1935 [10]. Since then they have been studied by Tolstoy and Usdin [12] and Abubakar [13]. The retrograde elliptic orbital motion of Rayleigh waves occurs in the M_1 branch. The motion is opposite in the M_2 branch. Each branch contains an infinite number of modes M_{1n}, M_{2n}, $n=1,\dots,\infty$. The manner in which the limits of the long and short wavelengths are connected, as well as results for the first two modes of symmetric vibration (M_{11} and M_{12}) and antisymmetric vibration (M_{21} and M_{22}) have been described [12, 13]. De [14] considered surface-wave propaga-

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tion in infinite granular and sandy soil media and also the propagation of plane waves in an infinite layer composed of sandy soil.

The existence of Stoneley wave [11] at the interface between two solid half-spaces would require an additional mode in the M_2 branch. The short wave limit of the phase velocity is equal to the velocity of the Stoneley waves at the interface. The short wave limit of the phase velocity for all other modes is the velocity of shear waves in the layer. Both the amplitudes and dispersion associated with a limited impulsive source have been discussed [15]. Such information is necessary for determinations of the amplitude and quantitiative effects on the depth of focus.

Rayleigh Waves in the Earth's Crust and Mantle. The properties of wave propagation in crystalline media are significant in seismology. At depths where pressure is great and temperature conditions uniform, magmas can supercool without freezing until large volumes suddenly crystallize. The subsequent decrease in volume causes an extremely violent contraction -- an earthquake. The generalized ray theory has been used to investigate conversion of primary modes to shear modes at the ocean bottom [16]. Elastic parameters of crystals were also established by this analysis.

The Rayleigh wave propagated in crystalline media has been discussed, and the Rayleigh wave velocity calculated for various classes of crystals [17, 18]. Early workers studied elastic waves in crystalline media [17, 18]. Beds of minerals were detected by measuring surface wave velocity.

The principal features of the Rayleigh wave dispersion for oceanic paths depend upon the properties of the water layer [19]. The propagation of Rayleigh waves in a system consisting of a liquid layer and an isotropic elastic half-space has been studied [9, 20, 21]. The problem has been extended to the case of aeolotropic material [22]. A comparison of theoretical and observed dispersions for paths across the Pacific Ocean [23] showed agreement over a large range of periods -- from 15 to 40 sec -- and group velocities -- from 1.5 to 4.0 km/sec.

Wave propagation in a liquid layer of finite depth overlying a semi-infinite half-space of crystalline material has been studied [17, 18]. Stoneley waves at the liquid-crystal and crystal-crystal interfaces were discussed for the limiting cases.

The effects of gravity on the classical problems of elastic waves and vibrations have been presented [19], as has the influence of compressibility [24]. It has been shown that the velocity of the Rayleigh wave is affected by gravity. Biot [25] assumed that gravity creates an initial hydrostatic stress and that the medium is incompressible. The role of such effects on the propagation of waves in an isotropic elastic layer has been considered [26], as have wave propagation in crystalline media [17] and the effect of initial stress on wave propagation in such media [27].

The horizontal component of motion on the seismogram of a small explosion usually exceeds the vertical, and the ellipses of motion are often tilted. Such waves are often called Rayleigh-type or pseudo-Rayleigh waves to distinguish them from theoretical Rayleigh waves, in which the vertical amplitude exceeds the horizontal [5]. The motion that precedes the direct motion of the particle is confined largely to the longitudinal component (in the direction of propagation). Such a pulse was first described by Leet [28, 29], who called the waves coupled waves. The propagation of Rayleigh waves across continents has been discussed [19, 23]. Only the M_{11} mode appears to be relevant to the propagation of earthquake-generated Rayleigh waves. The most severe earthquakes usually generate long period surface waves that circle the earth several times [2, 19, 23].

If the waves were Rayleigh waves, the direction of vibration of the horizontal components would parallel the direction of propagation; however, horizontal components parallel to the wave front are often found. Love [24] suggested that these waves can be accounted for by assuming that the values for elasticity and density of the earth's crust differ from those in the interior. He showed that transverse waves can propagate through such an outer layer without penetrating the interior.

The equation for Love waves is

$$\tan SH = \frac{\rho_2 V_{S_2}}{\rho_1 V_{S_1}} \left(\frac{V_{S_2}^2 - V_L^2}{V_L^2 - V_{S_1}^2} \right)^{1/2}$$

where

$$S = \frac{2\pi}{L}\left(\frac{V_L^2}{V_{S1}^2} - 1\right)^{1/2}$$

H is the thickness of the layer; L is wavelength; V_L is velocity of Love waves; and ρ_1, ρ_2, V_{S1}, and V_{S2} are the densities and shear-wave velocities in the surface layer and underlying medium respectively. Love waves are possible when $V_{S1} < V_L < V_{S2}$. It can be shown that the period equation expresses the constructive interference of the multiply reflected plane waves at angles of incidence beyond the critical angle $\sin^{-1}(V_{S2}/V_{S1})$.

The theory of Love waves in the presence of three surface layers was first studied by Stoneley [30] and later by De [31-34]. The latter also studied a generalized type of Love wave that is propagated along an internal stratum bounded on both sides by deep layers of material differing from the stratum in elastic properties. The possibility that such waves can propagate in crystalline media has also been discussed [18, 32, 35, 36]. De [33] also considered shear modes in anisotropic systems.

Lg and Rg Waves. Ewing and Press [36] described short-period surface waves which they called Lg and Rg. These waves are superposed on Love and Rayleigh waves over continental paths. They might be associated with higher-mode oscillations. Such waves have been studied by others [19, 23]. It has been found that the Lg phase can be used to determine whether the crust beneath a given area is continental or oceanic [19, 37, 38].

Waveguides in the Upper Mantle. The propagation of waves around the earth following an earthquake is probably due to the curvature of the earth. In theory two guides are possible in the upper mantle. First, the Mohorovičić discontinuity can act as a reflector for waves incident from below at angles near grazing. Second, a low velocity layer beneath the Mohorovičić can trap waves that have been refracted repeatedly. Such a layer is the Sofar channel in the ocean [23]. T phase and Sofar waves in the ocean have been discussed [19, 23].

Somigliana's theory, which has been summarized [39], is used to study propagation of seismic waves at the surface of a solid, elastic, isotropic, indefinite medium. The theory has been modified to allow a new interpretation of the Rayleigh equation, one that explains certain systems of seismic waves with no physical justification.

It has been shown [40] that $C_{i,j}$ waves satisfy the modified Somigliana theory and originate from SV waves incident to the base of the earth's crust under conducive angles. PL waves are also Somigliana waves; they are generated from P waves incident to the base of the earth's crust under conducive angles. Applications to the study of the earth's crust have been reported [40].

Waves due to Explosion. Blast waves, sonic booms and violent earthquakes release huge quantities of energy. The violent agitation created by such events is propagated as a wave, called a nonlinear wave, that continuously changes in profile, energy content, and speed. These waves differ from mild intensity waves known as linear waves, so called because two or more can be superimposed to produce a new linear wave. During this superposition, the profiles of the component waves do not become distorted.

Nonlinear waves cannot necessarily be superimposed to form a new wave governed by the same system of equations as can linear waves. As nonlinear waves propagate, such properties as density, pressure, temperature, velocity, and electromagnetic field change, producing discontinuities called shock waves.

If a blast occurs at a sufficiently high altitude, hydrodynamic effects can be ignored, and a uniform pressure distribution over the surface of the earth can be assumed. If the blast occurs at a relatively low altitude, strong shock waves occur, and it is assumed that the pressure distribution is confined to a certain area of the earth's surface. Low altitude explosions produce both surface and body waves. Mathematical study of the nonlinearity of low altitude waves provides information about the nature of the waves.

Underground nuclear explosions produce earthquakes that increase seismic activity and create cavities and craters. Underwater nuclear explosions provide seismic refraction profiles of oceanic regions that can be used to determine the position and thickness of different layers, velocity of seismic waves in those layers, and the position of Moho [41-48].

Surface waves encountered in geophysical prospecting, commonly called ground roll, have been described [19, 49]. Although ground roll consists predominantly of Rayleigh waves, the wave motion is not always coherent and regular [19] and often contains significant transverse components. Air-coupled Rayleigh waves and air-coupled ground roll have been discussed [19]. A sheet of ice floating on water is an efficient waveguide for the flexural mode of vibration, in which the velocity of propagation is less than the speed of sound in water [19, 23]. The possibility of a surface wave being transmitted over a heterogeneous medium of finite thickness lying in welded contact with a semi-infinite homogeneous elastic medium has been discussed [50].

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CIRCULAR SAW VIBRATION RESEARCH

C.D. Mote, Jr. and R. Szymani*

Abstract - Current research in circular saw vibration is evaluated. Fundamental investigations having potential long-term importance in the area of circular saw vibration are reviewed.

The reduction and control of circular saw vibration are essential to the improvement of wood surface quality and cutting accuracy, to the reduction of kerf losses and noise, and to the prolongation of tool life. Increasing economic pressures to control these characteristics have resulted in significant developments in circular saw cutter vibration research in the last two decades. That increased economic pressure is certain in future years assures continuing attention to circular saw vibration and thus more efficient cutting.

Promotion of continuing research efforts in cutting requires an evaluation of current research. Fundamental investigations that may have long-term importance to the circular saw vibration field are central to this discussion, and all pertinent papers known to the authors have been reviewed. The significance accorded the papers reviewed is of course based on the authors' interpretation of the work. In addition, the extensive literature cited includes journals and reports in various languages. The authors are truly apologetic if some significant work is missing. However, it is the diffuse nature of the references that makes a research review necessary and possibly essential.

Circular saw research topics not pertaining to fundamental saw vibration problems or those aimed at a specific process but not having general application are not included. Such distinctions are often difficult because vibration and saw design and operation are generally closely associated -- for example, should the design of a cutting tooth be considered a vibration problem? However, although tooth design affects both the cutting force and the heat flux created during cutting, and both are significant factors in saw vibration, only papers that relate directly to saw vibrations are included in this review.

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Papers in which vibration is a secondary consideration, such as those pertaining to tooth design, are not included.

VIBRATION ANALYSIS

The most general saw vibration can be considered a sum of individual saw vibration modes. These modes consist of an integer combination of nodal circles, m, and nodal diameters, n, as illustrated in Figure 1. The specific frequency of each mode ω_{mn}, termed the natural frequency, depends upon saw geometry, clamping ratio (a/b), material properties, and membrane stresses in the plane of the saw. These stresses are caused by thermal effects, initial stresses, and rotation. The constantly changing operating environment shifts the membrane stress state, causing a shift in the natural frequency of each mode. The saw vibration modes that most often dominate the transverse motion of the saw have zero to six nodal diameters and zero nodal circles.

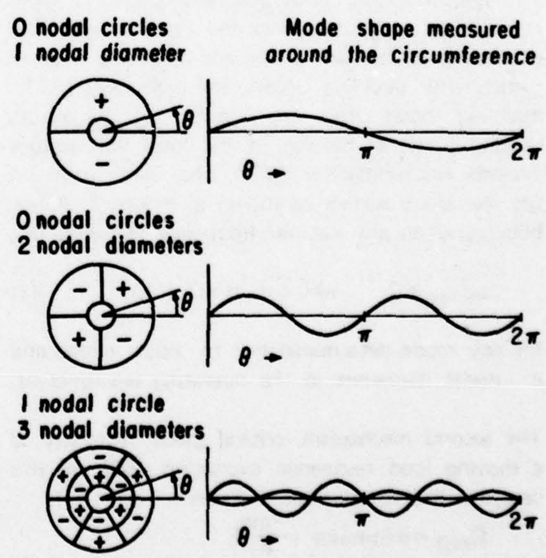

Figure 1. Schematic of Vibration Modes of a Rotating Circular Saw

In saw noise problems, modes with natural frequencies as high as 10 to 15 kHz can be significant even though their amplitudes are small. Tables of modal solutions have been published [61, 65]. Modification of the vibration of a saw requires either the alteration of vibration modes, a change in the driving forces, or both. These techniques are in fact employed everyday in the industry. Excitation of a saw blade can be altered by resharpening teeth and changing feed rate or rotational speed. Tensioning (initially stressing) or cooling the blade alters the vibration modes. These modes shift continuously with the changing environment.

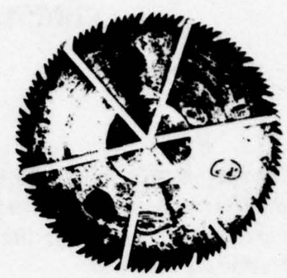

Figure 2. Example of a Three-Nodal-Diameter Buckling Mode. Tape on Surface is the Estimated Nodal-Diameter Location

THE CONCEPT OF STABILITY

Saws always vibrate, but they are not always unstable. Because instability enhances all the negative aspects of saw vibration, considerable research efforts have been directed toward identifying the mechanisms of instability [17, 24, 29, 52, 60-67, 69, 71, 73, 81, 82, 105, 106, 111, 112]. The mechanism of instability has thus far been the most important question studied in saw vibration research. Two instability mechanisms have been identified: static buckling, in which the saw assumes a fixed, harmonic shape of large amplitude; and critical speed instability, which is a moving load excitation. The static buckling mode generally consists of from zero to six nodal diameters and zero nodal circles, depending on the saw design and operating environment. After buckling occurs, the high spots of the buckling mode often rub against the workpiece, causing frictional heating. If the local temperature exceeds approximately 250°C, blue spots form on the saw blade surface as shown in Figure 2. A saw buckles when any natural frequency vanishes; i.e.,

$$\omega^2_{mn} \to 0 \qquad \text{where } m, n = 0, 1, 2, \ldots, \tag{1}$$

for any mode determined by m nodal circles and n nodal diameters in the operating environment.

The second mechanism, critical speed instability, is a moving load resonance excitation [65]. In this case, a critical rotation speed occurs.

$$\Omega_{crit} = \text{minimum}\ \left(\frac{\omega_{mn}}{n}\right), \quad \text{for all } m = 0, 1, 2, \ldots \quad n = 1, 2, 3, \ldots \tag{2}$$

The critical speed determines the maximum stable rotational speed Ω_{rot} of the saw. A saw will be unstable if

$$\Omega_{rot} \geqslant \Omega_{crit} \tag{3}$$

Critical speed instability always occurs before buckling and thus is more significant.

CRITICAL SPEED

The critical speed theory was applied to saws by Lapin [52] and Dugdale [24] although the concept dates from work published 50 years ago on turbines; e.g., Prescott [94] and Tobias and Arnold [120]. Since 1966 the theory has been developed such that product accuracy during production can be related to the theoretical critical speed [65, 66, 69, 71, 73].

Three frequencies must be clarified. The saw-based observer sees the true natural frequency of the saw ω_{mn} for fixed m and n.

$$\omega^2_{mn} \simeq \omega^{(0)^2}_{mn} + K\Omega^2_{rot} \tag{4}$$

The rotational stiffening represented by K is generally not large; it accounts for the curvature of the natural frequency-rotation curves in Figures 3 and 4.

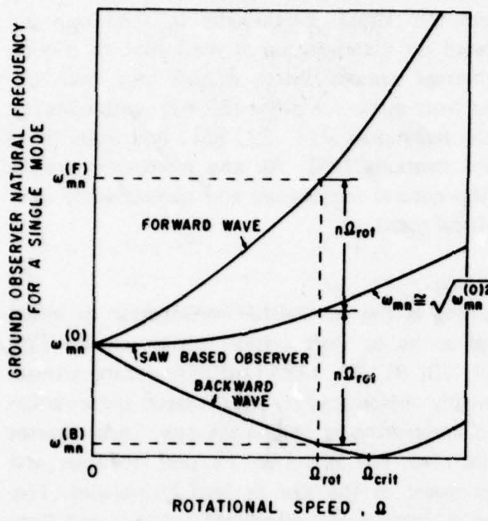

Figure 3. Frequency-Rotational Speed Diagram Showing Forward and Backward Traveling Waves and the Condition of Standing-Wave Resonance, or Critical Speed

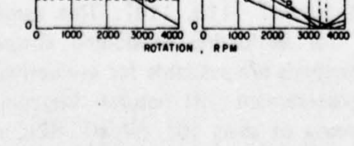

Figure 4. Frequency-Rotational Speed Diagrams. Solid curves are theoretical calculations; points are experimentally determined [67]

Usually Ω_{rot} increases the natural frequency of the mode (m, n) from the stationary saw $\omega_{mn}^{(0)}$ less than 5 percent. The ground-based observer sees two natural frequencies corresponding to this single mode.

$$\begin{aligned} \omega_{mn}^{(F)} &= \omega_{mn} + n\Omega_{rot} \quad \text{Forward Wave} \\ \omega_{mn}^{(B)} &= \omega_{mn} - n\Omega_{rot} \quad \text{Backward Wave} \end{aligned} \tag{5}$$

The mode (m, n) can be excited to resonance by excitation at either of the ground-based frequencies $\omega_{mn}^{(F)}$ and $\omega_{mn}^{(B)}$. As Ω_{rot} approaches Ω_{crit} from below, $\omega_{mn}^{(B)}$ approaches 0, and a zero-frequency -- or constant, stationary force -- excites resonance in the saw. During cutting, stationary low-frequency ground-based forces are present; the potential for this instability always exists.

The $\omega_{mn}^{(B)}$ do not approach zero for all modes (m, n) simultaneously. The particular mode in which a constant stationary force first occurs as the rotational speed is increased is called the critical speed mode and the rotation is called the critical speed. If the critical speed approaches the operating speed, instability occurs. Process variations that move the critical speed closer to the operating speed by shifting ω_{mn} and/or Ω_{rot} cause a deterioration in sawing accuracy. Process variations that move the critical speed away from the operating speed cause an improvement in sawing accuracy [71, 73].

An operating speed 15 percent below the critical speed, $\Omega_{rot} = 0.85\ \Omega_{crit}$ has been recommended [108, 121]. Note that the critical speed depends upon the blade temperature distribution during operation, and this distribution is not usually known. Stakhiev and Lyzhin [108] presented a nomogram for determining critical speeds for a wide range of saw diameter and thickness. They accounted for the clamping ratio and they assumed temperature differences between the periphery of the saw and its center.

Pashkov and Bodalev [92, 93] proposed a similar nomogram for determining optimum sawing parameters. Their nomogram was based on the assumed temperature differences between the rim and the clamping radius. However, this temperature difference does not specify the temperature distribution with sufficient accuracy; the approach should therefore be used cautiously. Approaches in which only

two or three points are used cannot treat the temperature properly because variations occur from process to process; in addition, blade stability is sensitive to temperature gradient.

If the saw geometry is approximately axisymmetric, any saw diameter is a potential nodal diameter. Nodal diameters can move on the saw. At the critical speed the nodal diameters of the resonance mode become fixed in space, establishing a modal wave that is stationary or standing in space [24, 52, 67]. If the saw is not axisymmetric, an arbitrary saw diameter is no longer a potential nodal diameter, and the standing wave, which depends upon the nodal diameter, cannot be established [27, 68, 120]. Although resonance and critical speed still occur, the instability does not lead to a standing wave, and the amplitude of the unstable response is reduced [27, 107, 120]. This is perhaps the most important contribution of edge slots in circular saws: they create asymmetry in the saw, thereby inhibiting the formation of standing waves.

MEMBRANE STRESSES

Initial stresses due to manufacturing and tensioning, rotational stresses, and thermal stresses do mechanical work during deformation of the blade. This work alters the transverse displacement of the saw under a given load and, in effect, increases or decreases blade stiffness. As the saw thickness is reduced, the deformation work attributable to the membrane stresses increases relative to the work done by the bending stiffness.

Similar theoretical explanations of the effect of membrane stresses on the saw stiffness have been presented independently by Dugdale [20, 21] and Mote [60, 61]. If the principal radial and tangential stresses are σ_{rr} and $\sigma_{\theta\theta}$, the work done under the saw transverse deflection $w(r, \theta)$ is given by

$$U_M = \int_0^{2\pi} \int_a^b [\sigma_{rr}(\frac{\partial w}{\partial r})^2 + \sigma_{\theta\theta}(\frac{1}{r}\frac{\partial w}{\partial \theta})^2] Hrdrd\theta \quad (6)$$

where
- a = clamping radius
- b = rim radius
- H = ½ disc thickness
- $\sigma_{\theta\theta}$ = hoop stress
- θ_{rr} = radial stress

The total work of deformation U includes a contribution due to saw bending, U_B. If the state of stress is known, equation (6) can be approximately evaluated, and the corresponding stiffness variation with membrane stress can be predicted. In a linear problem the stress components σ_{rr} and $\sigma_{\theta\theta}$ are calculated by superposition of the initial, rotational, and thermal stresses. These stresses have been calculated from stress functions [60, 61], with complex variable techniques [11, 22, 55], and with finite element methods [66]. All saw membrane stresses shift the natural frequencies and consequently alter the critical speed.

Tensioning

Tensioning is the purposeful introduction of initial stresses so as to shift critical speed upward [25, 60, 67, 73, 81, 91, 113, 114]. Tensioning stresses are usually introduced by local plastic deformation due to hammering or rolling the saw. These stresses can increase the effective flexural stiffness and critical speed of the saw at least 30 percent. Tensioning is particularly significant for thin and large diameter saws in which the effects of membrane stress on saw stiffness are large compared to the bending stiffness. The distribution of tensioning stresses have often been compared to those of a composite disc or multilayered cylinder in which radial stresses are compressive and hoop stresses vary from tensile to compressive across the composite interface (see Fig. 5).

Optimum tensioning for a given saw geometry, rotational speed, and temperature distribution can be specified for such criteria as critical speed [24, 65, 67, 69, 88, 89] and edge load buckling [11]. Because the state of residual stress in a saw blade depends on the operating environment, application of an optimal tensioning procedure requires detailed knowledge of the current environment. There is no method for the accurate, nondestructive measurement of initial stress in saw blades with resolution below 10 N/mm² [113, 114]. This resolution is necessary for evaluating tensioning stresses. Two indirect methods are available for evaluating residual stress: measurement of natural frequencies and critical speeds of saws [61, 67, 81, 82], and measurement of saw stiffness [4, 20, 21, 24, 25, 29, 91, 95, 113-115]. The measurement of natural frequencies and critical speeds determines the influence of initial stress on these values. The effect

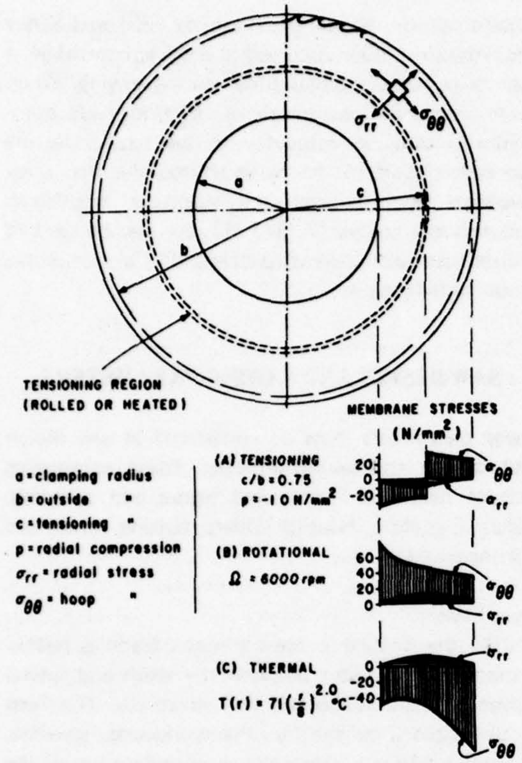

Figure 5. Distribution of Membrane Stresses in Saw Blades [40]

of initial stress in specific modes of deformation is determined by measuring saw stiffness. Dugdale [25] and Szymani and Mote [115] showed that the approximate modal stiffness can be used as a measure of tensioning.

The control of induced tensioning stresses by rolling or hammering is the most important -- and most difficult -- problem in tensioning. Significant early investigations on hammer tensioning and tension measurement included the development and comparison of theoretical and experimental analyses [1, 20, 21, 23]. Dugdale's work [23] is highly recommended. Pahlitzsch and Friebe [89] developed an empirical relationship in the roller tensioning problem involving the expansion of the rolled region, rolling load, and saw dimensions. Hackenberg [35], assumed spherical rolls and compared the rolling process to a series of spherical indentations. He extended the Hertz contact problem to include plastic deformation and derived an expression for predicting the rolling load required to initiate plastic deformation and the resulting tensioning stresses. The rolling load was replaced by an axisymmetric temperature distribution at the rolling radius in an analog formulation [43, 44]. The analysis was greatly simplified in this case, but the principal problem -- the relationship between the tensioning effort and the resulting initial stresses -- was not determined. Work on tensioning during the rolling process is currently underway by the authors of this review.

Two potential thermal tensioning methods have been developed. In one method, initial stresses sufficient to cause yielding are induced by local inductive heating [35, 36] or by subjecting the saw blade to thermal shock by laser pulses over a concentric annular area [39]. In the second method, thermal stresses insufficient to cause yielding are induced during the sawing process. The stresses allow continuous adjustment of the state of membrane stress and stability [5, 33, 62, 71, 73]. The method thus has excellent potential for on-line stability control of the saw.

Rotation

Possibly the most misunderstood concept in saw stability is the role of rotational stresses. The widely held belief that tension is introduced to counteract the effect of centrifugal forces is incorrect without qualification [61, 65, 69]. Although rotational stresses cannot promote instability, rotation can cause instability through the mechanisms of moving load resonance and critical speed. The point is that the instability is caused by the moving load and not by the centrifugal forces. If the saw were stationary and the load were allowed to go around it, critical speed and resonance would still exist -- and could be calculated by equation (2) -- but the rotational stresses would be zero.

Thermal Stresses

Thermal stress depends upon the coefficient of thermal expansion of the saw blade material and the saw temperature distribution induced by the cutting process (Fig. 5). Measurements of saw temperature during production have been published as illustrated in Figure 6 [71, 73].

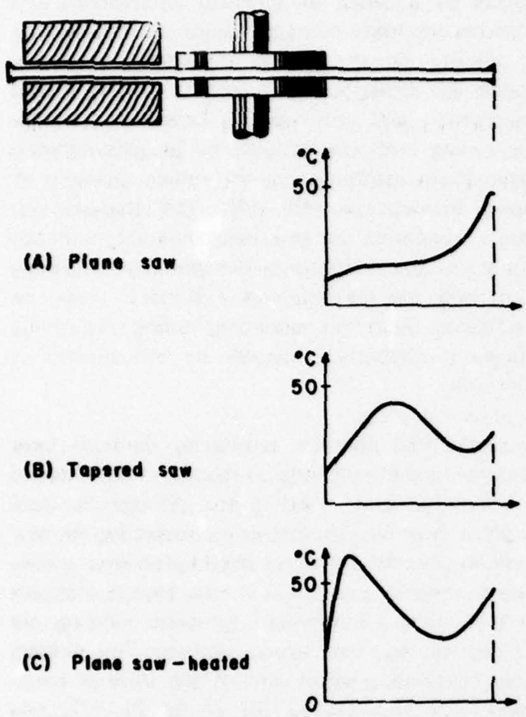

Figure 6. Typical Temperature Distribution in Circular Saws during Cutting [71]

Thermal stress is not difficult to determine if the temperature is known. Thermal stresses are the dominant cause of saw instability when a saw is initially stable and subsequently becomes unstable. An increase in rim temperature increases the zero frequency and often one nodal diameter natural frequency and decreases the two and higher nodal diameter natural frequencies. As a consequence, the critical speed decreases, and the saw is less stable. If the hub temperature is increased, the zero frequency and often one nodal diameter natural frequency decrease and the second and higher natural frequencies increase [69, 77]. The critical speed increases, although buckling (oil-canning) in the zero nodal diameter mode can occur. Such a process is stabilizing if the saw is not initially buckled.

Adjustment of thermal stresses during sawing has been discussed [5, 32, 33, 56, 61, 62, 71, 73, 96]. Thermal tensioning in the form of frictional heating of the saw blade has been used for decades in Scandinavia. Grube, Sanev, and Pashkov [33] and Sanev and Pashkov [99] discussed feedback control as a way to regulate thermal stress during sawing. When blade vibration was excessive, friction pads automatically came in contact with the blade. Heating the central part of the blade shifted the frequency spectrum and reduced the vibration amplitude. Tapered saw blades [7, 37, 71] can also be used to induce favorable thermal distribution through workpiece-blade friction.

SAW DESIGN AND SAWING PARAMETERS

Many parameters must be considered in saw design and during the sawing process. These parameters include heat flux, compound blades and damping, radial edge slots, floating collars, cutting force, and cutting speed.

Heat Flux

During the cutting process the saw blade is heated primarily by friction between the teeth and lateral surfaces of the blade and the workpiece. This heat is dissipated into the air, the workpiece, sawdust, the saw blade, and the teeth. A consideration of the saw temperatures that occur during cutting must distinguish between the quasi-equilibrium operating temperature of the entire blade and the local heat sources -- those, for example, on the tooth face or tip. The maximum temperature measured during production on 550 mm diameter plane saws at feed speeds of 20 to 30 m/min was 40 to 60°C above the ambient temperature, with occasional readings of 100°C above the ambient temperature [71]. Temperatures at tooth cusps are apparently significantly larger: approximately 300°C [78] and to 450 to 500°C on the tooth face [13]. High temperatures at the rim are responsible for the unfavorable thermal stress in the saw blade described earlier as well as decreases in the strength of the steel saw and the wear resistance of the teeth. A temperature of 300°C, for example, causes a reduction of about 10 percent in the yield strength of saw steel; 450°C causes a reduction of approximately 25 percent [6]. Heating the bearings has been shown to improve saw blade stability [67].

Compound Blades and Damping

Compound or laminated saws and collars have been of interest since 1963 [15, 31, 59]. Laminated saw

blades currently consist of either two steel plates separated by a dissipative layer or a single plate with a dissipative layer positioned away from the workpiece. The energy is dissipated by surface interaction and through work [122].

Saw vibration with eddy current damping from opposing 2,000 G.D.C. electromagnets has been investigated [109]. The vibration amplitudes of blades with diameters of 400 to 500 mm and thicknesses ranging from 2.5 to 3.5 mm were reduced 56 percent during idling and 12 percent during sawing.

Radial Edge Slots

The intended purpose of slots in saws is to allow thermal expansion without development of stresses. As a result of expansion the frequency spectrum shifts upward, increasing the critical speed for instability. Experiences of various investigators [7, 57, 83] support the introduction of uniformly spaced narrow radial slots or enlarged gullets [42] to improve stability. On the other hand, independent reports state that radial edge slots are relatively ineffective [2, 107] and recommend the introduction of annular slots near the hub (Fig. 7).

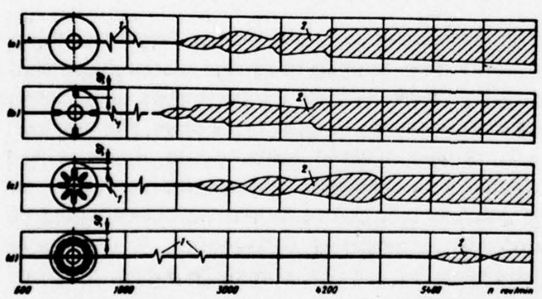

Figure 7. Effect of Slots on the Vibration Amplitude of a Rotating Disc [107]
Disc geometry: 500 mm dia, 1 mm thick (clamping ratio 0.2)
(a) disc without slots; (b) and (c) discs with radial slots; (d) disc with annular slots; 1 - forced vibrations; 2 - free vibrations

The number and length of slots have been determined. In most cases saw blades have four or five radial slots up to 1/6 the length of the saw radius [55, 83]. Theoretical analyses of the effect of slots and holes that have been conducted [66, 68] and verified experimentally [27] show that the slotted saw, which is geometrically unsymmetrical, does not form a standing wave at critical speed. The number of resonant frequencies of the saw doubles because of a frequency splitting phenomenon associated with the slots, and resonance can occur at each frequency [65]. When the slotted saw is excited at resonance, the saw amplitude is less than that in the symmetric saw (no slots) experiencing the same excitation. The amplitude is reduced because the response energy of the saw is distributed throughout the spectrum [27].

Floating Collar Saw

A saw with collars that float on the arbor and that is guided at the periphery is a relatively recent design concept [9, 58, 117]. Kerf reductions from 9.5 mm to 2.5 mm or less have been reported possible [9]. Theoretical studies on the stability of the floating clamping collar circular saw have been conducted by Mote [74, 75], but the analysis did not predict the reported benefit in saw stability from the floating collar. The positive effect of the floating collar might result from reduced peripheral heating during cutting. The importance of dissipation and transmissibility of the peripheral excitation has not yet been considered.

Cutting Force

Until recently the effect of cutting force on saw blade stability was assumed to be negligible and thus was not included in stability analyses. Cutting force was of interest only as an indicator of power requirements [48, 49, 54]. The first theoretical and experimental investigations of the stresses resulting from cutting forces and the radial in-plane edge load contribution to saw stiffness were conducted by Gurkin [34], Dugdale and Squires [22], and Stakhiev and Lyzhin [108]. The effects of tensioning on buckling have also been included in analyses [11] and some theoretical guidelines for improving both the buckling and vibrational characteristics of saws proposed [11]. Saw buckling under two-dimensional in-plane edge loads has been investigated [53, 72, 97]. It was shown [97] that the concentrated tangential buckling load is approximately three times the normal buckling load on a centrally clamped disc.

Such analyses have demonstrated that, in general, the

edge load shifts the fundamental frequency to a lower value and alters its mode shape and that the remaining natural frequencies are relatively unchanged. When the critical speed mode is not the fundamental, the edge load appears to have little influence on critical speed instability [97]. Stability analyses with concentrated edge loads are difficult because the saw stress analysis and vibration problems are no longer axisymmetric, and the buckling and vibration modes are dissimilar.

Researchers have concluded that the cutting forces are small in comparison to the edge buckling load. According to Stakhiev and Lyzhin [108] the critical radial (normal) buckling loads for saws of 500 mm diameter and 1.2 and 2.5 mm thickness are 0.98 kN and 3.92 kN respectively. The radial component of the cutting force under average sawing conditions for softwoods ranges from 0.12 kN to 0.15 kN. A radial cutting force of 0.15 kN has been reported for saw blades of 500 mm diameter and 2 mm thickness when pine wood is sawed at 3,000 RPM at a rate of 70 m/min [34]. It is difficult to isolate cutting forces due to initial cutting impact, friction, and transport of sawdust [119]. The cutting force increases with the feed rate per tooth; for feed rates greater than 0.5 mm per tooth, the *force is* approximately proportional to feed speed [8, 38]. For feed rates in the range 0 to 0.5 mm per tooth the exponential law of Bershadskii [8] applies [80].

The cutting forces described above have only a small effect on saw blade stability so long as the forces remain in the plane of the blade. An increase in saw loading during cutting leads to vibration excitation according to Kotesovec and Loss [50]. They also concluded that the introduction of radial edge slots increases saw vibration during the cutting of solid wood because of reduced blade stiffness. Pahlitzsch and Rowinski [83] recommended that the feed rate, or bite per tooth, should be large because vibration damping increases. They also observed that saw vibrations can be damped by using large cutting depths and by introducing radial edge slots. The mechanism by which energy is dissipated is not clear to the authors of this review, but it must be associated with a complex interaction of blade and workpiece.

Pahlitzsch and Friebe [86] concluded that the transverse vibration amplitude during cutting with thin blades does not have to be larger than that occurring with thicker blades. Their investigations showed that the vibration amplitude decreases with higher cutting speed, with blade protrusion, and for relatively thin blades, with depth of cut. They associated this last result with stiffening of the saw blade by centrifugal forces. The increase in cutting force and heat flux at higher speeds can be expected to be at least as significant to saw stability as rotational speed. In a later study, Pahlitzsch and Friebe [87] observed that surface roughness increased slightly with an increase in saw blade thickness and with the depth of cut. The increased surface roughness was attributed to the increased total cutting force and vibration amplitude. An increase in damping with the feed rate per tooth has also been observed [123], but Skjelmerud [102] concluded that a larger bite per tooth results in poorer sawing precision and surface quality. Fukui [30] conducted extensive studies on sawing conditions and surface roughness and also concluded that surface roughness increases with feed rate and decreases with increasing rotational speed and cutting height. Reducing the number of teeth, which is desirable for reduction of noise, results in a poorer surface [3].

The contradictions in the cutting height-saw thickness-vibration damping-roughness relationships might possibly occur because the parameters under investigation were not isolated in all cases. For example, uncontrolled thermal stress would influence the results, and dissipation mechanisms dependent on interaction between blade and workpiece would be difficult to reproduce and control. It is virtually impossible to conduct a study in which only one parameter is varied.

Cutting Speed

An increase in cutting speed to improve surface quality has been recommended as a result of all research. Researchers generally agree that higher cutting speeds increase power consumption at fixed production rates, but such speeds, which reduce bite per tooth, result in higher surface quality.

AERODYNAMIC VIBRATION AND NOISE

Surface quality and productivity necessitate circular saw cutting velocities ranging from 50 to 70 m/sec,

and there has been a trend toward higher cutting speeds for a long time. Cutting speeds up to 100 m/sec for cross-cutting and up to 120 m/sec for ripsawing were recommended in 1954 [51]. A high cutting velocity is often accompanied by noise in excess of 90 dB(A), however, and although the noise problem in woodworking has been recognized for some time [118], the first extensive investigations were begun in 1960 [16] and continued thereafter [26, 59, 79, 84, 85, 100]. The rotating saw is excited as the saw teeth interact with the induced air flow and the workpiece. This excitation is important in the analysis of both saw noise and saw vibration. Attention is this section is directed particularly to the interaction of the aerodynamic source of noise and saw teeth-induced air flow.

Pahlitzsch and Rowinski [84] observed that the formation of high-frequency, self-excited vibrations during idle running depends upon the surface area of the tooth and the shifting eddies behind the teeth. In a later study, Pahlitzsch and Friebe [85] concluded that large amplitude saw blade vibrations are caused by alternating vortices that are shed from each tooth in the form of a Karman vortex sheet. That whistling, or resonance, occurs when the frequency of vortex separation coincides with a natural frequency of the rotating saw was supported by associating noise frequencies with predicted shedding frequencies. Air flow at the tooth was not measured. Water channel tests resulted in similar vortex shedding conclusions [46, 116].

The sound from a rigid rotating disc with no teeth has been analyzed experimentally [12]. The aerodynamic sources were at the periphery of the disc and had a classic dipole character. A dipole source for saws was suggested [98], and the model was then modified [41] to include contributions from monopole sources in an attempt to fit experimental observations to classical point sources. In another investigation [103] aerodynamic excitation was assumed to be a linear combination of classical monopole, dipole, and quadrapole noise sources; it was concluded that dipole noise, vorticity shedding noise, and incident turbulence noise are probably the dominant noise sources. Recent results [101] include an amplified quadrapole model for the dominant noise source of the saw. The model is supported by sound power versus rim velocity measurements; no comparison of relative source strengths of induced-air flow measurements were included.

Other observations [14, 26, 47, 70] have not shown Karman vortex shedding, but point to sustained wake oscillation as the source of high-frequency (whistling) noise. A theoretical model of galloping oscillation has been proposed [14] and is supported by experimental results. Variation in the transverse force coefficient of the tooth was associated with saw rim speed, and it was concluded that the dominant noise source was of a dipole type.

The noise studies described above demonstrate that, in general, the exciting force results from an interaction between the induced air flow and the rotating saw blade. This incident flow is turbulent and three dimensional and depends upon geometry and rotation of the saw blade and the geometry and number of teeth. It is the opinion of the authors of this review that excitation from classical Karman vortices is not likely to be important because the probability of the occurrence and strength of such a discrete vortex formation appears to be quite low.

Some important practical observations on saw noise have been summarized [16, 59, 79, 84, 100].

- During idle running, a high frequency whistle or self-excited vibration may occur that is more intense than the noise during sawing. The noise intensity increases with increasing RPM, saw diameter, blade thickness, and number of teeth.
- During sawing a linear relationship exists between noise intensity, cutting velocity, and feed rate.
- The noise generation mechanism is sensitive to the design o the teeth and their number and arrangement 'pitch).

Meins [59] listed four methods for reducing saw vibration noise: 1) a second disc rotating with the saw blade to provide damping, 2) fixed damping plates near the saw blade, 3) lamination of the blade with a viscoelastic layer, and 4) use of dissipative saw guides. The best results were obtained with laminated (compound) blades; noise reductions ranged from 10 to 20 dB(A). Similar results have been reported elsewhere [31]. Laminated blades [31, 59] have been developed and are now commercially available [122].

Investigations of saw vibration damping with magnetic fields (eddy current damping) showed a noise reduction of up to 15 dB in saws 2 to 3.6 mm thick, 300 to 500 mm in diameter, and rotating at speeds of 1,000 to 4,000 RPM [110]. The use of irregularly spaced teeth (irregular pitch) distributes the excitation energy of cutting over a broader spectrum [18, 19, 90]. This in turn reduces blade repsonse in situations in which an excitation harmonic becomes centered on a saw blade resonance. A reduction exceeding 15 dB(A) has been reported in this process.

Seemingly subtle modifications of the tooth profile itself are significant factors in saw blade excitation [26]. A radical noise reduction of 6 to 9 dB(A) during cutting and 23 to 25 dB(A) during idling has been achieved by tapering both sides of the teeth [45, 101]. The aerodynamics of the gullets is also significant insofar as noise is concerned. Conflicting recommendations for solving aerodynamic noise problems are attributable to an inadequate understanding of noise source mechanisms. The drilling and/or filling of slots and holes modifies existing sources and may, as a result, improve the noise problem, but the physical explanation of the source excitation is incomplete. Details of air-tooth interaction are not known and the driving of individual teeth by air and the flow of air around and between teeth have not been investigated but all are fundamental to solving the noise source problem.

CLOSING REMARKS

Vibration reduction and control in circular saws is accomplished through saw design, manufacturing process specification, and, more recently, feedback control of saw repsonse. The physical mechanisms of saw instability and vibration are partially understood in terms of the critical speed of the saw, and the critical speed provides a criterion for comparisons of competitive designs. Research on design and process specification has been sufficiently well developed that notable improvements are possible in most processes. Implementation of research results to actual processes is not a trivial task, but many suggestions have proven successful in practice.

Feedback vibration control is relatively new to the cutting process. Control can take place by a spectral shifting technique, such as blade cooling and/or heating [76] or initial stressing, and control can be accomplished by an external forcing method, as with saw guides and electromagnets [27, 28]. The criteria of blade performance include surface quality, cutting accuracy, blade vibration, and power requirements. Increasing costs of raw materials and processing and decreasing costs of electronics and instrumentation point to continued expansion of active research.

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ERRATA: Balancing of Linkages, by R.S. Berkof et al
Volume 9. No. 6. June 1977

Page 3. Paragraph (2)

The second rule is a generalization of the method of linearly independent vectors [4]; the full force balance of a balanceable planar n-link mechanism is possible with an "apparent" minimum number of n/2 counterweights.

Page 4. Equation (6)

$$m_i{}^*r_i{}^* = \left[(m_i r_i)^2 + (m_i{}^o r_i{}^o)^2 - 2\, m_i m_i{}^o r_i r_i{}^o \cos(\theta_i - \theta_i{}^o), \right]^{1/2}$$

Page 5. Paragraph (3)

The techniques of full force and moment balancing have been applied to a slider-crank mechanism [2]. Linkages with and without a slider offset were considered. Linearly independent vector balancing techniques for general four-bar linkages can start with a two-mass replacement of the coupler link at its pivots if these masses are represented by complex numbers [12].

Page 6. Figure 4

Figure 4. Configuration of Shafts and Balancing Weights Showing Positive Dimensions and Rotations (from [38])

Page 6. Paragraph (1)

In one case the shaking force was minimized and the magnitude of the shaking moment was limited [31].

Page 7. Paragraph (8)

A draglink mechanism with a compensating mass on the coupler was studied [28] with a technique developed by Hockey and Sherwood.

Page 8. Paragraph (1)

This approach was developed to smooth the torque requirements of such devices as those in antenna drive systems. Springs or cam-driven masses have also been used to smooth input torque [3]. Spring parameters have been synthesized to generate a desired time repsonse of the mechanism [14].

BOOK REVIEWS

PROBABILISTIC THEORY OF SHIP DYNAMICS

W.G. Price and R.E.D. Bishop
Halstead Press, New York, New York

robabilistic theory has emerged as a good tool ı the design of objects subjected to random loading. tochastic processes have supplanted the useful, ut at times, unrealistic deterministic (sinusoidal) timulus. The theory has been used in designing ircraft, land transportation, buildings, and off-hore structures. The application to ship design ıas been a long time coming since Longuet-Higgins ›ublished his classical paper on statistical distribu-:ion of heights of sea waves and St. Dennis and ᵓierson published their paper on motion of ships ın a confused sea. Price and Bishop's little book vas well worth waiting for. The book consists of 14 chapters and is grouped into three parts.

Part I includes Chapters I-IV. Elementary probability principles are presented, and probability distribution for single- and joint-random variables are introduced. The various stochastic terms, viz., expected values, mean square value, covariance, are adequately explained in simple terms. The Gaussian probability density function for single and two random variables, the Rayleigh distribution, and the well-known Chi distribution and Poisson distribution are described in very few pages.

Chapters V and VI conclude Part I. They include descriptions of random processes and auto- and cross-correlations and auto- and cross-variances. Stationary and ergodic which are the heart of linear random vibration analysis are adequately defined. The authors introduce Fourier integrals and power spectral density and show derivation of the latter by use of auto-correlation and Fourier integrals. The relationship between cross-spectral density and cross-correlation is explained, and stochastic processes are introduced.

Part 2 consists of three chapters on ship dynamics. The authors begin with simple waves and proceed to more complex random waves. The spectral wave densities are discussed with reference to the ITT wave spectrum, the Darbyshire wave spectra, and the Pierson-Moskowitz wave spectra; all are related to the Beaufort scale. Zero crossings in the Gaussian probability density function (broadband) and the Rayleigh distribution (narrow band) are explained. Although the explanations are adequate, the truncation ratio and crest factor, important in understanding the Gaussian and Rayleigh distributions are not mentioned.

Part III (Chapters 10-13) considers the deterministic theory of ship motion and randomly disturbed seas. The theory of seakeeping is in reality the solution of random vibrations of linear systems applied to ship dynamics. The combination of heave, pitch, and roll motions produces a virtual motion that can be expressed in probabilistic terms. The last chapter considers nonlinear motion of ship-wave systems and briefly mentions Caughey's equivalent linearization and Crandall's perturbation method, neither of which is often seen in random vibration texts.

The reviewer commends the authors for their excellent little book but feels that they should have discussed certain aspects of partial and multiple coherences and referred to random fatigue of structures and transfer functions. All of these topics are assuming greater importance in the study of the random vibration of structures. The reviewer also believes that a short section on data reduction and application would have made the book more self-contained. This book should be of great value to marine engineers, however.

Herb Saunders
General Electric Company
LSTGD
Schenectady, NY 12345

FLOW-INDUCED VIBRATION

R.D. Blevins
Van Nostrand-Reinhold, 1977

This book constitutes a useful and conscientious survey of a number of the more common phenomena of flow-induced vibration. The work is by a practitioner who has had to deal with the engineering side of these phenomena. The emphasis is on the construction and manipulation of empirical analytical models by which the phenomena can be forecast and accounted for in design.

The chapter headings are: Introduction, Dimensional Analysis, Vortex-Induced Vibration, Galloping Vibrations and Stall Flutter, Instabilities of Tube Rows and Tube Arrays, Vibrations Induced by an Oscillating Flow, Vibrations Induced by Turbulence, Damping of Structures, Sound Induced by Vortex Shedding, Vibrations of a Pipe Containing a Fluid Flow, and Ship Motion in a Seaway.

The work, which reflects the author's personal experience and bias, appears to represent the state to which the author's thinking had advanced up to the time of writing. Thus, the opus is not to be construed either as exhaustive relative to the whole field nor focused - instructional in the sense of a textbook aimed primarily at students.

Seen in this light, the somewhat uneven treatment of the various topics should not disorient the reader. For example, the subjects of vortex shedding and galloping are treated rather extensively, though with some important omissions (such as the details of the Hartlen–Currie model). On the other hand, classical and bridge-type flutter are not dealt with practically; and, some casually misdirected statements occur in these latter contexts.

The problems of building buffeting in Wind Engineering are outlined at some length, though related broad areas of Wind Engineering are, perhaps of necessity, not touched upon. The problems of a ship in a seaway are outlined, but random wave forces on offshore structures are not strongly covered.

On the whole, however, as a conscientious presentation of one man's experience, the book succeeds, representing much responsible underlying study and work. The book offers the serious analytically-minded practicing engineer help in grappling with the numerous new problems of flow-induced vibration that arise in modern design.

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SHORT COURSES

JULY

9TH ANNUAL INDUSTRIAL PRODUCT NOISE CONTROL INSTITUTE

Dates: July 10-14, 1978
Place: Union College, Schenectady, NY
Objective: For engineers, designers, environmental health specialists and managers concerned with noise and vibration control. This course will provide information on the theory measurement and economics of noise reduction. The course will cover the latest information on the nature of sound and noise control, including noise criteria, airborne sound distribution, vibration control, and noise signature analysis. Other topics include how noise is produced by different types of engineering equipment such as compressors, electric motors, fans, valves, and transformers.

Contact: Graduate Studies & Continuing Education, Union College, Wells House - 1 Union Avenue, Schenectady, NY 12308 - (518) 370-6288.

INSTRUMENTATION, MEASUREMENTS ENGINEERING AND APPLICATION

Dates: July 17-21, 1978
Place: Union College, Schenectady, NY
Objective: This course is designed for technicians and engineers involved in the field of instrumentation and measurements who wish to be informed on the latest "State-of-the-Art". The data reduction techniques that can be used coinciding with the instrumentation to resolve a particular problem will be included. Major topics will include: transducer design, applications and limitations, engineering the test program, recording techniques, data reduction and interpretation, and case histories. These will be applied to both static and dynamic measurement.

Contact: Graduate Studies & Continuing Education, Union College, Wells House - 1 Union Avenue, Schenectady, NY 12308 - (518) 370-6288.

COMPUTER WORKSHOP IN FINITE ELEMENT METHODS OF ANALYSIS FOR STRESS AND OTHER FIELD PROBLEMS

Dates: July 24-28, 1978
Place: Union College, Schenectady, NY
Objective: To develop the basic formulations of the finite element structural analysis, to examine practical applications and to present Fortran IV computer programs for both 2D and 3D problems. The programs will be applied to tutorial and student generated problems.

Contact: Graduate Studies and Continuing Education, Union College, Wells House - 1 Union Avenue, Schenectady, NY 12308 - (518) 370-6288.

COMPUTER WORKSHOP IN EARTHQUAKE AND STRUCTURAL DYNAMICS

Dates: July 24-28, 1978
Place: Union College, Schenectady, NY
Objective: To develop the basic formulations of structural dynamic analysis for linear and nonlinear systems, to examine practical applications to earthquake and structural dynamics and to present Fortran computer programs for multi degree-of-freedom systems. The programs will be applied to tutorial and student generated problems.

Contact: Graduate Studies and Continuing Education, Union College, Wells House - 1 Union Avenue, Schenectady, NY 12308 - (518) 370-6288.

FINITE ELEMENT METHOD IN MECHANICAL DESIGN

Dates: July 24-28, 1978
Place: The Univ. of Michigan, Ann Arbor, MI
Objective: This course is intended for engineers working in mechanical design where knowledge of stresses, displacements, or vibratory motion is important. No previous experience with finite elements is assumed. The course will familiarize the attendee with finite element modeling concepts and will

review the fundamentals on which the method is based. A number of practical examples will be presented.

Contact: Engineering Summer Conferences, 400 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490.

NOISE CONTROL ENGINEERING

Dates: July 31-August 4, 1978

Place: Univ. of Michigan, Ann Arbor, MI

Objective: This course provides engineers and managers with comprehensive knowledge of noise-control engineering and criteria for application to practical problems.

Contact: Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490.

AUGUST

PYROTECHNICS AND EXPLOSIVES

Dates: August 14-18, 1978

Place: Philadelphia, PA

Objective: This seminar combines the subjects of pyrotechnics and solid state chemistry along with explosives and explosive devices. It will be practical so as to serve the men working in the field. Presentation of theory is restricted to that necessary for an understanding of basic principles and successful application. Coverage emphasizes recent effort, student problems, new techniques, and applications. The prerequisite for this seminar is a bachelor of science degree in engineering or equivalent.

Contact: Registrar, The Franklin Institute Research Labs., Philadelphia, PA 19103 - (215) 448-1236.

SEPTEMBER

7TH ADVANCED NOISE AND VIBRATION COURSE

Dates: September 11-15, 1978

Place: Institute of Sound and Vibration Research, University of Southampton, England

Objective: The course is aimed at researchers and development engineers in industry and research establishments, and people in other spheres who are associated with noise and vibration problems. The course, which is designed to refresh and cover the latest theories and techniques, initially deals with fundamentals and common ground and then offers a choice of specialist topics. The course comprises over thirty lectures including the basic subjects of acoustics, random processes, vibration theory, subjective response and aerodynamic noise which form the central core of the course. In addition, several specialist applied topics are offered, including aircraft noise, road traffic noise, industrial machinery noise, diesel engine noise, process plant noise and environmental noise and planning.

Contact: Dr. J.G. Walker or Mrs. O.G. Hyde, Institute of Sound and Vibration Research, The University, Southampton, S09 5NH, England.

MACHINERY VIBRATION

Dates: September 20-22, 1978

Place: Cherry Hill, New Jersey

Objective: Lectures and demonstrations on rotor-bearing dynamics, turbomachinery blading, and balancing have been scheduled for this Vibration Institute-sponsored seminar. The keynote address on the development of balancing techniques will be given on the first day along with sessions on modal analysis, oil whirl, and computer programs. Simultaneous sessions on rotor-bearing dynamics and turbomachinery blading will be held on the second and third days. The following topics are included in the rotor-bearing dynamics sessions: critical speeds, stability, fluid film bearing design and analysis, balancing sensitivity, generator rotor balancing, gas turbine balancing, and industrial balancing. The sessions on turbomachinery blading feature excitation and forced vibration of turbine stages, structural dynamic aspects of bladed disk assemblies, finite element analysis of turbomachinery blading, steam turbine availability, metallurgical aspects of blading, torsional-blading interaction, and field tests of turbogenerator sets. Each participant will receive a proceedings covering all seminar sessions and can attend any combination of sessions.

Contact: Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312)654-2254

NEWS BRIEFS

news on current and Future Shock and Vibration activities and events

EIGHTH U.S. NATIONAL CONGRESS OF APPLIED MECHANICS

The U.S. National Committee on Theoretical and Applied Mechanics and UCLA Extension announce the Eighth U.S. National Congress of Applied Mechanics on June 26-30, 1978 at UCLA. The five-day U.S. National Congress of Applied Mechanics, organized by the U.S. National Committee on Theoretical and Applied Mechanics, takes place at four-year intervals. This is the principal national meeting on applied mechanics and is the counterpart of the International Congress sponsored by the International Union of Theoretical and Applied Mechanics. The National Congress provides a forum for invited survey lectures by renowned authorities and brief contributed talks on the latest advances in broad areas of applied mechanics. The Congress is open to all interested members of the mechanics community. Fifteen invited lectures and over 400 contributed papers are presented in the fields of Dynamics, Fluid Mechanics, Geotechnical, Mechanics of Materials, Solid Mechanics and Structures. For further information, contact the Short Course Program Office, 6266 Boelter Hall, UCLA Extension, Los Angeles, CA 90024 - (213) 825-1295 or 825-3344.

FATIGUE OF ENGINEERING MATERIALS & STRUCTURES

This international journal is devoted to research in the fatigue behavior of engineering materials and endeavours to draw together all the science, technology and engineering relevant to the understanding and control of the fatigue problem. As its principal task, the journal will focus attention on the fact that the study of fatigue now calls for a truly interdisciplinary approach involving mechanics, mathematics, metallurgy, materials science, computer science, physics and chemistry. For example, one of the great gaps in present understanding concerns the effects of the environment on fatigue. To advance here the engineer must come to understand the fundamentals of corrosion, and reciprocally, the various sciences involved must become more alive to the engineering problems. It is intended that all materials will be represented in the journal. Although the nature of the problem today will dictate that the main focus will be on metals, polymers and composites, attention will also be paid to ceramics, concrete, wood and glass. It is hoped that most papers published in the journal will be of direct interest to the engineer, particularly to the design engineer and the research engineer responsible for the design of sophisticated components.

CALL FOR PAPERS SEVENTH VIBRATION CONFERENCE

The seventh biennial ASME Conference on Mechanical Vibration is scheduled to be held as part of the 1979 Design Technical Conference in St. Louis, MO on September 9-12, 1979. The St. Louis Section of ASME will be host. The theme of this conference will be the applied aspects of vibration engineering. Emphasis will be on technology and experience associated with real apparatus, systems and problems. Technical papers are solicited in the areas indicated below. Abstracts should be submitted to the appro-Program Subcommittee Chairman on ASME Form M & P 1903 by October 1, 1978. This form is available from ASME, 345 E. 47th St., New York, NY 10017, (212) 644-7722 or from the Program Chairmen. Complete manuscripts, in quadruplicate, are due by December 1, 1978 to the appropriate Subcommittee Chairman. Accepted papers will be preprinted for the conference and will also be considered for publication in the Journal of Mechanical Design Engineering.

Program Chairman: Professor F.C. Nelson
Dept. of Mechanical Engineering
Tufts University
Medford, MA 02155
(617) 628-5000 Ext. 240

Areas to be covered are Rotating Machinery, Vibration Reduction and Control, Structural Dynamics, Finite Element Vibration Analysis, Mechanical Signature Analysis, Machinery Noise, Blade Vibration, Fluid-Structure Interaction, Recent Developments in the Acquisition and Analysis of Vibration Data, Recent Developments in Vibration Instrumentation and Experimental Methods, and Special Problems in Vibration.

VIBRATION DAMPING

A course on vibration damping will be held October 23-26, 1978 at the University of Dayton, Ohio. The science and art of utilizing the vibration damping properties of viscoelastic materials to reduce the undesirable effects of vibration and noise on structures and equipment has become well developed in recent years. Unfortunately, these techniques are not well known by the technical community; and consequently, this valuable tool is not used as much as it should be. This course is designed to teach the background, analytical methods, and experimental technqiues required to design and apply damping treatments for solving vibration problems. Methods for incorporating damping treatments in new designs will also be taught. The practical approach to problem solutions and step-by-step procedures will be emphasized. For further information contact: Dale H. Whitford, University of Dayton, Research Institute, Dayton, Ohio 45469 - (513) 229-4235.

STANDARDS REVIEW

American National Standards Institute Committee S2 Mechanical Vibration and Shock

The semiannual meeting of ANSI S2 was held at the 95th meeting of the Acoustical Society of America in Providence, Rhode Island on May 16, 1978. A meeting of the Technical Advisory Group for ISO/TC 108 was held in conjunction with the S2 meeting. The status of standards activity within the various S2 working groups was discussed. Major planning for the forthcoming ISO/TC 108 meeting was conducted at the TAG meeting. Delegates for the various technical and plenary meetings were selected.

ANSI Committee S2-74 under chairman Peter Baade continues its activity on the development of standards on the measurement of structural and mechanical mobility. A set of five standards covering various aspects of mobility are being prepared. The first document covers basic definitions and transducers.

The machinery vibration committees continue to work on the development standards for the measurement and analysis of machinery condition. ANSI Committee S2-65, Balancing Technology, continues to work under the guidance of Dr. Neville F. Rieger. Presently this committee is active at the international level with the development of flexible rotor balancing standards. Presently this committee is preparing a document for the forthcoming ISO/TC 108 meeting in Berlin. Efforts are underway to revise the document, Balancing Quality of Rotating Rigid Bodies (ISO Standard 1940). The development of a standard on techniques of machinery vibration measurement by S2-71 has been completed. This document has been submitted to ISO/TC 108/SC2/Wg1 (Vibration Levels in Machines) for consideration as an ISO standard. Committee S2-76 is in the process of preparing a draft international standard on shaft vibration measurement in preparation for the ISO/TC 108/SC2 meeting to be held in Berlin in late September, 1978.

International Standards Organization Committee TC 108 Mechanical Vibration and Shock

Meetings of ISO/TC 108; its Subcommittee (Balancing, Including Balancing Machines); Subcommittee 2 (Measurement and Evaluation of Mechanical Vibration and Shock as Applied to Machines, Vehicles, and Structures), and Subcommittee 3 (Use and Calibration of Vibration and Shock Measuring Instruments); and its working groups 1, 4, 5, 8, and 11 (Terminology, Vibration Testing Equipment, Vibration and Shock Isolators and Dampers, Statistical Analysis of Vibration and Shock Data, and Design Evaluation Methods for Vibration and Shock, respectively) will be held in Berlin September 25 through October 4, 1978.

Environmental Sound Workshop

More than 70 individuals from various voluntary standards-setting organizations and government agencies met in Deerfield Beach, Florida, for a three-day workshop to help develop guidelines suitable for use in developing voluntary standards applicable to governmental noise regulations.

The workshop was held 7-9 December near Florida Atlantic University. The U.S. Environmental Protection Agency (EPA) sponsored the event in cooperation with the National Bureau of Standards. The Acoustical Society of America organized and managed the workshop on behalf of the American National Standards Institute (ANSI).

Among the voluntary standards organizations represented at the workshop were the Society, ANSI, and the Society of Automotive Engineers. Other Federal government agencies attending were the Department of Labor, Commerce, Transportation, HEW, the U.S. Air Force, and the General Services Administration.

The goal of the workshop was to prepare a plan and guidelines for the future development of voluntary standards for defining the sound output from both stationary and moving noise sources, for characterizing the performance of noise-control devices, and for measuring and evaluating the effects of environmental noise.

The workshop on Environmental Sound was organized by the Co-Chairmen, Henning E. von Gierke and Kenneth M. Eldred. Avril Brenig, ASA Standards Manager, was responsible for all of the arrangements with EPA and with Florida Atlantic University, which was responsible for local arrangements.

The Workshop was divided into two divisions, the Guidelines Division and the Planning Division. Under the leadership of Kenneth M. Eldred and Henry Thomas, who headed the Guidelines Division, an extensive draft report on guidelines for development of noise measurement standards was prepared. Individuals concerned with both moving and stationary sources were represented. The guidelines document addresses those factors to be considered in specifying the scope and application of a measurement procedure, the instrumentation and ambient conditions during the test, and the supplemental information necessary to support the procedures and provide the rationale for its provisions.

The Planning Division, headed by Henning E. von Gierke and David Goldman, was subdivided into three working groups: P1 on Physical Acoustics and Instrumentation, chaired by George C. Malling, Jr.; P2 on Human Response, chaired by William Melnick; and P3 on Noise Control Elements, chaired by Richard Guernsey.

For more information write or call Ms. Avril Brenig (212/661-9404), Standards Manager, Acoustical Society of America, 335 East 45th Street, New York, New York 10017.

ABSTRACT CATEGORIES

ANALYSIS AND DESIGN

- Analogs and Analog Computation
- Analytical Methods
- Dynamic Programming
- Impedance Methods
- Integral Transforms
- Nonlinear Analysis
- Numerical Analysis
- Optimization Techniques
- Perturbation Methods
- Stability Analysis
- Statistical Methods
- Variational Methods
- Finite Element Modeling
- Modeling
- Digital Simulation
- Parameter Identification
- Design Information
- Design Techniques
- Criteria, Standards, and Specifications
- Surveys and Bibliographies
- Tutorial
- Modal Analysis and Synthesis

COMPUTER PROGRAMS

- General
- Natural Frequency
- Random Response
- Stability
- Steady State Response
- Transient Response

ENVIRONMENTS

- Acoustic
- Periodic
- Random
- Seismic
- Shock
- General Weapon
- Transportation

PHENOMENOLOGY

- Composite
- Damping
- Elastic
- Fatigue
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- Inelastic
- Soil
- Thermoelastic
- Viscoelastic

EXPERIMENTATION

- Balancing
- Data Reduction
- Diagnostics
- Equipment
- Experiment Design
- Facilities
- Instrumentation
- Procedures
- Scaling and Modeling
- Simulators
- Specifications
- Techniques
- Holography

COMPONENTS

- Absorbers
- Shafts
- Beams, Strings, Rods, Bars
- Bearings
- Blades
- Columns
- Controls
- Cylinders
- Ducts
- Frames, Arches
- Gears
- Isolators
- Linkages
- Mechanical
- Membranes, Films, and Webs
- Panels
- Pipes and Tubes
- Plates and Shells
- Rings
- Springs
- Structural
- Tires

SYSTEMS

- Absorber
- Acoustic Isolation
- Noise Reduction
- Active Isolation
- Aircraft
- Artillery
- Bioengineering
- Bridges
- Building
- Cabinets
- Construction
- Electrical
- Foundations and Earth
- Helicopters
- Human
- Isolation
- Material Handling
- Mechanical
- Metal Working and Forming
- Off-Road Vehicles
- Optical
- Package
- Pressure Vessels
- Pumps, Turbines, Fans, Compressors
- Rail
- Reactors
- Reciprocating Machine
- Road
- Rotors
- Satellite
- Self-Excited
- Ship
- Spacecraft
- Structural
- Transmissions
- Turbomachinery
- Useful Application

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

ANALYSIS AND DESIGN

ANALYTICAL METHODS

(Also see Nos. 786, 845, 851)

78-767

Collocation, Dissipation and 'Overshoot' for Time Integration Schemes in Structural Dynamics

H.M. Hilber and T.J.R. Hughes

Div. of Structural Engrg. and Structural Mechanics, Dept. of Civil Engrg., Univ. of California, Berkeley, CA., Intl. J. Earthquake Engr. Struc. Dynam., 6 (1), pp 99-117 (Jan-Feb 1978) 12 figs, 1 table, 22 refs

Key Words: Dynamic structural analysis

The concept of collocation, originally used by Wilson in the development of dissipative algorithms for structural dynamics, is systematically generalized and analyzed. Optimal schemes within this class are developed and compared with a recently proposed family of dissipative algorithms, called α methods. The α methods are found to be superior on the basis of standard measures of dissipation and dispersion. The tendency to overshoot is an important and independent factor, should be considered in an evaluation of an implicit scheme. The basis for studying overshoot is discussed and the optimal collocation and α methods are compared.

78-768

Finite Element Method for Random Response of Structures Due to Stochastic Excitation

S.S. Dey

Inst. f. Statik und Dynamik der Luft- und Raumfahrtkonstruktionen, Stuttgart Univ., West Germany, Rept. No. ISD-221, 97 pp (1976)
N78-11438

Key Words: Stochastic processes, Finite element technique, Multidegree of freedom systems

Application of the finite element method to analyze the response of multi-degree linear elastic structures subjected to stationary random stochastic loading is described. Two methods, the complex matrix inversion method and the normal mode method, were used to compute the responses. The basic theory for these two approaches and relevant statistics are presented in detail. In the first approach, the global stiffness and mass matrices are used as input data; in the second approach, the eigenvalues and eigenvectors are used as input for random response calculations.

NUMERICAL ANALYSIS

78-769

Stability of Numerical Integration Techniques for Transient Rotor Dynamics

A.F. Kascak

Lewis Res. Center, NASA, Cleveland, OH, Rept. No. NASA-TP-1092; E-9252, 22 pp (1977)
N78-10474

Key Words: Rotor-bearing systems, Dynamic stability, Numerical analysis, Finite element technique

A finite element model of a rotor bearing system was analyzed to determine the stability limits of the forward, backward, and centered Euler; Runge-Kutta; Milne; and Adams numerical integration techniques.

OPTIMIZATION TECHNIQUES

78-770

SMOP-Structural Mass Optimisation Programme

European Space Agency, Paris, France, Rept. No. ESA-SP-133, 47 pp (July 1977) (Proc. of lectures held at ESTEC, Noorwijk, Neth., June 9-10, 1977)
N78-11175

Key Words: Optimization, Satellites, Spacecraft, Dynamic structural analysis, Dynamic tests, Modal tests

The development of a minimum mass core structure configuration for a communication type satellite and the verification of the design was discussed in the context of the ESA Structural Mass Optimization Program (SMOP). Papers on dynamic analysis and testing of a mass optimized satellite structure and on the experimental verification of SMOP structure dynamic analyses by means of modal survey testing were given.

78-771

SMOP 2 - Dynamic Analysis and Testing of a Mass-Optimized Satellite Structure

P.A. Villalaz and U. Schibli

Contraves Corp., Zürich, Switzerland, In: ESA SMOP - Struct. Mass Optimisation Programme, pp 1-19 (July 1977)
N78-11176

Key Words: Optimization, Satellites, Spacecraft, Dynamic structural analysis, Dynamic tests, Modal tests

A survey of the development, manufacturing, and testing activities which led to a strictly mass optimized satellite structure is provided. The Structural Mass Optimization Program (SMOP) was part of the Supporting Technology Program (STP) for the European Communications Satellite (ECS). The dynamic investigations performed on the primary satellite structure were used to create a dynamic model called SMOP within a follow-up program. A modal survey test and a vibration test on the structure were carried out in order to investigate its dynamic performance characteristics and to confirm its dynamic behavior predicted by an eigenvalue and a frequency response analysis.

78-772

Experimental Verification of SMOP - Structure Dynamic Analyses by Means of Modal-Survey Testing

M. Degener

Inst. for Aeroelasticity, Deutsche Forschungs- und Versuchsanstalt f. Luft- und Raumfahrt, Göttingen, West Germany, In: ESA SMOP - Struct. Mass Optimisation Programme, pp 25-36 (July 1977)
N78-11177

Key Words: Optimization, Satellites, Spacecraft, Normal modes, Dynamic analysis, Modal tests, Damping effects

The rigid body modes and the elastic normal modes were measured; correlation of the results and the pertaining analytical results are discussed. On the basis of the modal survey test data a dynamic response analysis was performed. The results are compared with the shaker test. The influence of damping coupling and damping nonlinearity was studied.

STATISTICAL METHODS

78-773

Stochastic Linearization by Data Dependent Systems

S.M. Pandit

Dept. of Mech. Engrg., Michigan Technological Univ., Houghton, MI, J. Dyn. Syst., Meas. and Control, Trans. ASME, 99 (4), pp 221-226 (Dec 1977) 2 tables, 21 refs

Key Words: Stochastic processes, Nonlinear systems, Machine tools, Chatter

The paper presents and illustrates a method of stochastic linearization of nonlinear systems. The system response to white noise excitation is modeled by a differential equation, which provides the necessary transfer function. An application to machine tool chatter vibrations illustrates stability assessment and modal analysis.

FINITE ELEMENT MODELING

(See No. 769)

SURVEYS AND BIBLIOGRAPHIES

78-774

Parametric Vibration. Part II: Mechanics of Nonlinear Problems

R.A. Ibrahim and A.D.S. Barr

Arab Organisation for Industrialisation, Sakr Factory for Developed Industries, P.O. Box 33, Heliopolis, Cairo, Egypt, Shock Vib. Dig., 10 (2), pp 9-24 (Feb 1978) 1 fig, 168 refs

Key Words: Reviews, Parametric response, Nonlinear theories

The effects of various nonlinearities on the behavior of parametrically excited systems and the mechanics of systems with explicit and implicit time-dependent coefficients are reviewed in this second article of the series.

78-775

Recent Developments in Statistical Energy Analysis

R.H. Lyon

Dept. of Mech. Engrg., Massachusetts Inst. of Tech., Cambridge, MA 02139, Shock Vib. Dig., 10 (2), pp 3-7 (Feb 1978) 38 refs

Key Words: Reviews, Statistical energy methods, Buildings, Ships

This is a review of recent work related to the basic theory of and developments in statistical energy analysis. Most of the cited references have appeared since 1972. Some of the more interesting new applications have been to marine systems.

78-776
Linear Elastic Wave Propagation. An Annotated Bibliography: Part 1
R.A. Scott
Dept. of Applied Mech. and Engrg. Science, Univ. of Michigan, Ann Arbor, MI 48109, Shock Vib. Dig., 10 (2), pp 25-41 (Feb 1978) 287 refs

Key Words: Reviews, Wave propagation, Isotropy

This survey of the literature on linear elastic wave propagation consists of two parts. Part I covers homogeneous isotropic media. Part II covers discretely nonhomogeneous media, continuous nonhomogeneous media, anisotropic media, and diffraction.

MODAL ANALYSIS AND SYNTHESIS

(Also see Nos. 816, 894)

78-777
Stability and Instability of Certain Normal Modes
G. Pecelli and E.S. Thomas
Dept. of Mathematics, SUNY, Albany, NY, Mech. Res. and Comm., 4 (6), pp 423-426 (June 1977) 2 figs, 6 refs

Key Words: Modal analysis, Normal modes

The stability of normal modes of certain systems of coupled nonlinear oscillators are investigated. Previous treatments of such problems frequently use a small parameter (often the energy) to obtain stability criteria. The methods described here apply for arbitrary parameter values. The main tools in the analysis are the Twist Theorem of Kolmogorov-Arnol'd-Moser, the classical theory of Hill's equation, and the theory of normal forms of planar maps.

COMPUTER PROGRAMS

GENERAL

78-778
Complex Eigenvalue Extraction in NASTRAN by the Tridiagonal Reduction (FEER) Method
M. Newman and F.I. Mann
Analytical Mechanics Associates, Inc., Jericho, NY 11753, Rept. No. NASA-CR-145258; AMA-77-17, 42 pp (Sept 1977)
N78-11420

Key Words: Computer programs, Eigenvalue problems

An extension of the Tridiagonal Reduction (FEER) method for complex eigenvalue analysis in NASTRAN is described. As in the case of real eigenvalue analysis, the eigensolutions closest to a selected point in the eigenspectrum are extracted from a reduced, symmetric, tridiagonal eigenmatrix whose order is much lower than that of the full size problem. The reduction process is effected automatically, and thus avoids the arbitrary lumping of masses and other physical quantities at selected grid points.

78-779
Validation of a Flexible Aircraft Take-Off and Landing Analysis (FATOLA)
H.D. Carden and J.R. McGehee
Langley Res. Center, NASA, Langley Station, VA., Rept. No. NASA-TP-1025; L-11704, 68 pp (1977)
N78-10049

Key Words: Computer programs, Aircraft, Impact shock, Landing, Takeoff, Simulation

Modifications to improve the analytical simulation capabilities of a multi-degree-of-freedom flexible aircraft take-off and landing analysis (FATOLA) computer program are discussed. The FATOLA program was used to simulate the landing behavior of a stiff body X-24B reentry research vehicle and of a flexible body supersonic cruise YF-12A research airplane. The analytical results were compared with flight test data, and correlations of vehicle motions, attitudes, forces, and accelerations during the landing impact and rollout are reported.

78-780
Eigenvalue Programs for Building Structures
J.L. Humar
Dept. of Civil Engrg., Carleton Univ., Ottawa, Canada, Intl. J. Computers and Struc., 8 (1), pp 75-91 (Feb 1978) 5 figs, 3 tables, 4 refs

Key Words: Computer programs, Eigenvalue problems, Natural frequencies, Mode shapes, Buildings

This paper presents two eigenvalue routines for calculating the mode shapes and frequencies of engineering structures, in particular, building structures. Both routines are developed

on the assumption that the mass matrix is diagonal, with all diagonal terms non-zero, and that the stiffness matrix is symmetric. The inverse power method with shifts is used in each case; the only important differences between the two routines is in the allocation of storage and in the procedure used for inverting the matrices. Illustrative examples are presented to demonstrate the computational efficiency that can be achieved by the use of the inverse power method with shifts, provided the shift points are located judiciously and an appropriate convergence criterion is employed.

78-781

A Methodology for Seismic Evaluation of Existing Multistory Residential Buildings. Volume 2. Computer Users' Manual

C.W. Pinkham and G.C. Hart

Barnes (S.B.) and Associates, Los Angeles, CA., Rept. No. HUD/RES-1200, 181 pp (June 1977)

PB-274 610/5GA

Key Words: Computer programs, Multistory buildings, Earthquake resistant structures, Standards and codes

This manual describes a method of structural analysis, design, and analysis of costs for the determination of strengthening of existing multi-story residential buildings to conform to the basic earthquake force requirements of the 1973 Uniform Building Code. The report is presented in three volumes. Volume 2 contains Appendix D - Input Data Forms, and Appendix E - Computer Program Users' Manual.

78-782

Adaptation of SAP IV Computer Code to Aircraft Shelter Analysis Program

H.L. Schreyer, J. McCharen, and J.W. Berglund

Eric H. Wang Civil Engrg. Research Facility, New Mexico Univ., Albuquerque, NM, Rept. No. AFCEC-TR-76-31, 192 pp (June 1976)

AD-A046 970/0GA

Key Words: Aircraft, Protective shelters, SAP (computer programs), Computer programs

This report is concerned with the adaptation of a linear, static and dynamic structural analysis computer code (SAP IV) to aircraft shelter structural components. A number of features were added to the documented version of SAP IV to decrease the time and effort necessary to set up practical problems including a Free Format Input Program, a stress/displacement versus time plot capability, and a specific procedure for approximating the nonlinear behavior of cracked concrete.

78-783

SPAN: User's Summary. Addendum

G.C. Mitchell

Naval Construction Research Establishment, Dunfermline, UK, Rept. No. NCRE/R630-ADD, DRIC-BR-57609, 25 pp (Mar 1977)

AD-A047 021/1GA

Key Words: Computer programs, Stiffened plates, Grids (beam grids), Dynamic structural response

SPAN is a computer program for static and dynamic analysis of stiffened plates and grillages. The addendum contains a precis of R630, plus additional information on computing times, control-cards and permissible problem size. It may be regarded as superseding that document for the conversant SPAN user.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 817, 818, 822, 840, 863, 884)

78-784

Sound Transmission Through Jet Engine Nozzles and Broadband - Noise Amplification by Pure Tone Excitation in Free Jets

D. Bechert, E. Pfizenmaier, and U. Michel

Inst. f. Turbulenzforschung, Deutsche Forschungs- und Versuchsanstalt f. Luft- und Raumfahrt, Berlin, West Germany, Rept. No. DLR-1B-257-77/9, 14 pp (1977)

N78-11801

Key Words: Jet engines, Jet noise, Sound transmission

The problem of sound transmission from internal sources in jet engines is discussed. The transmission path for the essential part of sound energy coincides with that of the internal flow downstream to the nozzle exit. Sound then crosses the external free jet flow on its way to the far field, and an interaction takes place between sound from internal sources and the free turbulence within the jet. Possibilities for altering this broadband amplification are described.

78-785
Acoustic Radiation from a Venturi Type Flowmeter Due to Hydrodynamic Excitation (LWBR Development Program)
G.H. Weidenhamer and R. Lindner
Bettis Atomic Power Lab., Westinghouse Electric Corp., West Mifflin, PA, ASME Paper No. 77-DET-165

Key Words: Hydrodynamic excitation, Acoustic fatigue, Instrumentation response

A discrete frequency sound generated by steady-state flow in an LWBR venturi type flowmeter presented a potential fatigue problem. The frequency was independent of flow rates but varied with temperature as the sonic velocity-temperature relationship for water. Hydrodynamic excitation, found to be due to the steady flow past the edge of the pressure tap holes, was eliminated.

PERIODIC

78-786
The Peak Harmonic Response of Locally Non-Linear Systems
R.K. Miller and W.D. Iwan
Univ. of California, Santa Barbara, CA., Intl. J. Earthquake Engr. Struc. Dynam., 6 (1), pp 79-87 (Jan-Feb 1978) 5 figs, 1 table, 5 refs

Key Words: Periodic response

This paper presents an approximate analytical technique for determining the steady-state response of a class of systems with spatially localized non-linearity. A method of finding the amplitude peaks in various modes is presented. Numerical examples illustrate the nature and accuracy of the results of the approximate analysis.

78-787
Excitation of Composite Motions in Linear Elastic Bodies by One-Dimensional Harmonic Oscillation
D. Maciulevičius and R. Nogis
Vilniaus Inžinerijos ir Statybos Institutas, Vilnius, Lietuvos TSR, Lietuvos Mechanikos Rinkinys: Lietuvos TSR Aukštųjų Mokyklų Darbai, Vilnius, No. 1 (16), pp 18-23 (1976) 4 figs, 2 refs
(In Russian)

Key Words: Harmonic excitation, Vibration response, Structural members

Conditions, under which a simple harmonic excitation may result in a complex response of an elastic body, are investigated. This occurs when the frequencies of two modes are similar and the oscillator frequency is tuned between them. Another example is a circular plate damped at its inner edge and freely supported outer edge.

SEISMIC

(Also see Nos. 781, 864, 865, 881, 897)

78-788
Aseismic Design Implications of Near-Fault San Fernando Earthquake Records
V.V. Bertero, S.A. Mahin, and R.A. Herrera
Dept. of Civil Engrg., Univ. of California, Berkeley, CA., Intl. J. Earthquake Engr. Struc. Dynam., 6 (1), pp 31-42 (Jan-Feb 1978) 8 figs, 24 refs

Key Words: Seismic design, Buildings

The results of an analytical study of a building severely damaged during the San Fernando earthquake indicate that such severe, long duration acceleration pulses were the cause of the main features of the observed structural damage. The implications of such pulses on current aseismic design methods, particularly those used to establish design earthquakes, are examined for buildings located near potential earthquake faults. Analytical studies of the non-linear dynamic response of single and multiple degree-of-freedom systems to several near-fault records as well as to a more standard accelerogram are reported.

78-789
An Alternative Definition of Instructure Response Spectra
T.S. Atalik
Bechtel Espana, S.A., Madrid, Spain, Intl. J. Earthquake Engr. Struc. Dynam., 6 (1), pp 71-78 (Jan-Feb 1978) 5 figs, 1 table, 10 refs

Key Words: Structural response, Response spectra, Seismic response

A procedure is described to compute the instructure spectra of a structure without a time-history analysis and with a high confidence level. It is shown that spectral values obtained by filtering the prescribed ground motion first through the structure and the resulting motions through simple oscillators are equal to maximum structural responses developed when the order of filtration is reversed. Based on the

preceding concept a method is presented to construct instructure response spectra utilizing the response spectrum technique. Recommendations are made to increase the confidence levels of the instructure response spectra to that of the ground design response spectrum.

78-790

Modeling and Analysis for Seismic Adequacy in Air Handling Unit Enclosures -- The Effects of Structural Reinforcement

C.F. Zorowski and J.M. Nau
North Carolina State Univ., Raleigh, NC, ASME Paper No. 77-DET-136

Key Words: Air conditioning equipment, Enclosures, Seismic design, Reinforced structures

The effects of structural reinforcement on the seismic adequacy of air handling unit enclosures by focusing on their expected frequency response during seismic excitation is investigated. Analytical results are presented which describe how the natural frequencies of the units vary with enclosure dimensions, internally mounted component mass, and bracing stiffness and geometry. The effects of model simplification on the validity of the modal extraction are investigated by analysis of models of the massive component sections of the enclosures.

78-791

A Substructure Method for Earthquake Analysis of Structures Including Structure-Soil Interaction

J.A. Gutierrez and A.K. Chopra
Dept. of Civil Engrg., Univ. of California, Berkeley, CA., Intl. J. Earthquake Engr. Struc. Dynam., 6 (1), pp 51-69 (Jan-Feb 1978) 10 figs, 27 refs

Key Words: Seismic excitation, Ground motion, Earthquake response, Interaction: soil structure

A general substructure method for analysis of response of structures to earthquake ground motion, including the effects of structure-soil interaction, is presented. The method is applicable to complex structures idealized as finite element systems and the soil region treated as either a continuum, for example as a viscoelastic halfspace, or idealized as a finite element system. Spatial variations in the input motion along the structure-soil interface of embedded structures or along the base of long surface supported structures are included in the formulation.

78-792

Dynamic Response of a Submerged Hemispherical Shell to Earthquake Motions

N. Akkas
Dept. of Civil Engrg., Middle East Technical Univ., Ankara, Turkey, Intl. J. Earthquake Engr. Struc. Dynam., 6 (1), pp 89-98 (Jan-Feb 1978) 4 figs, 24 refs

Key Words: Seismic response, Interaction: structure-fluid, Hemispherical shells, Submerged structures

The dynamic response of hemispherical shells in a fluid medium to ground motion is studied numerically. In the analysis, linear thin shell theory is used and the fluid is assumed to be compressible and inviscid. The effect of the duration of the ground motion on the dynamic response is studied using two forcing functions, one with a very short duration and the other in the form of a Heaviside function. As special cases, dynamic responses of the shell in vacuo and of a rigid hemisphere in a fluid medium are investigated. The results are valid also for a ring-stiffened complete spherical shell accelerating in an acoustic medium.

SHOCK

(Also see Nos. 779, 878)

78-793

Light Airplane Crash Tests at Impact Velocities of 12 and 27 m/sec

E. Alfaro-Bou and V.L. Vaughan
Langley Res. Center, NASA, Langley Station, VA., Rept. No. NASA-TP-1042; L-11426, 52 pp (Nov 1977)
N78-10034

Key Words: Crash research (aircraft), Experimental data

Two similar general aviation airplanes were crash tested at the Langley impact dynamics research facility at velocities of 13 and 27 m/sec. The facility, instrumentation, test specimens, and test method are described. Structural damage and accelerometer data are discussed.

78-794

Parachute Opening Shock Calculations with Experimentally Established Input Functions

H.G. Heinrich and D.P. Saari
Univ. of Minnesota, Minneapolis, MN, J. Aircraft, 15 (2), pp 100-105 (Feb 1978) 11 figs, 1 table, 21 refs

Key Words: Parachutes, Shock response

Parachute opening shock calculations with experimentally established area- and velocity-time functions are shown which, in combination with the momentum and continuity equations, yield force-time histories that satisfactorily agree in shape and force level with measured force-time diagrams.

78-795

Train-to-Train Rear End Impact Tests. Volume 1. Pre-Impact Determination of Vehicle Properties

R.L. Anderson and P.L. Cramer

Dynamic Science Div., Ultrasystems, Inc., Phoenix, AZ, Rept. No. DOT-TSC-FRA-76-7-1, FRA/ORD-76/303.1, 102 pp (Mar 1977)

PB-274 416/7GA

Key Words: Collision research (railroad), Impact tests, Computerized simulation

Nine train-to-train rear end impact tests were performed, and the tests were documented. Volume 1 summarizes the vehicle properties obtained prior to the impact tests. These vehicle properties were used in computer simulation of the impact tests and included weights, pitch moments of inertia, spring rated, vertical center of gravity location, and linear dimensions.

78-796

Train-to-Train Rear End Impact Tests. Volume II. Impact Test Summaries

R.L. Anderson and P.L. Cramer

Dynamic Science Div., Ultrasystems, Inc., Phoenix, AZ, Rept. No. DOT-TSC-FRA-76-7-11, FRA/ORD-76/303.11, 124 pp (Mar 1977)

PB-274 417/5GA

Key Words: Collision research (railroad), Impact tests

Nine train-to-train rear end impact tests were performed, and the tests were documented. Volume II describes the impact tests. The impact tests were remotely controlled with impact speeds ranging from 3 to 30 mph.

78-797

Train-to-Train Rear End Impact Tests. Volume III. Appendix A: Impact Test Data. Appendix B: Report of Inventions

R.L. Anderson and P.L. Cramer

Dynamic Science Div., Ultrasystems, Inc., Phoenix, AZ, Rept. No. DOT-TSC-FRA-76-7-111, FRA/ORD-76/303.111, 342 pp (Mar 1977)

PB-274 418/3GA

Key Words: Collision research (railroad), Impact tests, Experimental data

Nine train-to-train rear end impact tests were performed, and tests were documented. Volume III is an appendix to Volume II. It contains the original data of the impact test.

TRANSPORTATION

(Also see Nos. 795, 796, 797)

78-798

An Investigation of Ride Quality Rating Scales

T.K. Dempsey, G.D. Coates, and J.D. Leatherwood

Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TP-1064, 48 pp (Nov 1977)

N78-11696

Key Words: Ride dynamics, Human response, Scaling

An experimental investigation was conducted for the combined purposes of determining the relative merits of various category scales for the prediction of human discomfort response to vibration and for determining the mathematical relationships whereby subjective data are transformed from one scale to other scales. There were 16 category scales analyzed representing various parametric combinations of polarity, that is, unipolar and bipolar, scale type, and number of scalar points.

78-799

Ride Quality Research Techniques: Section on Scaling Techniques

Transportation Systems Center, Cambridge, MA, Workshop on Vehicle Ride Quality, pp 65-72 (July 1977)

N78-11709

Key Words: Scaling, Ride dynamics

Scaling techniques appropriate for the measurement of ride quality subjective responses are evaluated. The major focal points of interest are summarized in succeeding paragraphs as follow: scope of scaling, goal of scaling, category scales; including polarity, scalar points, and whether the scale is discrete or continuous in nature, need and use of adjectives and/or adverbs, role and use of magnitude estimation, multiple response measures, and related topics.

78-800

On Scaling Techniques

Transportation Systems Center, Cambridge, MA, Workshop on Vehicle Ride Quality, pp 144-156 (July 1977)
N78-11711

Key Words: Scaling, Ride dynamics, Transportation systems

An introductory review of the principles of scaling with emphasis on ride quality work is presented. It will be divided into six parts as follows: definition of scaling, scope and goals of scaling, scaling techniques (with emphasis on rating scale, magnitude estimation procedures and cross-modality matching), laboratory vs. field studies, multivariate analysis, and selected references.

78-801

Ride Control Techniques

Transportation Systems Center, Cambridge, MA, Workshop on Vehicle Ride Quality, pp 73-143 (July 1977)
N78-11710

Key Words: Ride dynamics, Transportation systems

The state-of-the-art in ride quality control techniques for all the primary modes of transportation and the needs for the future are summarized.

78-802

Ride Quality Research Techniques: Section on General Techniques

Transportation Systems Center, Cambridge, MA, Workshop on Vehicle Ride Quality, pp 38-64 (July 1977)
N78-11708

Key Words: Ride dynamics, Transportation systems

Information is gathered about the methods currently used for the study of ride quality in a variety of transportation modes by a variety of research organizations, including universities, federal agencies, contracting firms, and private industries. Detailed descriptions of these techniques and their strengths and weaknesses, and identifying the organizations using such methods are presented.

PHENOMENOLOGY

COMPOSITE

78-803

On Harmonic Waves in Layered Composites

S. Minagawa and S. Nemat-Nasser
Dept. of Mech. Engrg., Denkitsushin Univ., Chofu, Tokyo, Japan, J. Appl. Mech., Trans. ASME, 44 (4), pp 689-695 (Dec 1977) 6 figs, 11 refs

Key Words: Composites, Laminates, Harmonic waves, Wave propagation

For harmonic waves propagating in a layered elastic composite, approximate dispersion relations are developed. Both waves propagating in the direction of the layers, and those propagating obliquely to this direction, are considered. The layer problem is treated as a special case of fiber-reinforced elastic composites. For illustration, the approximate results are compared with the exact ones for the special case of homogeneous layers.

78-804

The Effect of Reflections on Nonlinear, Transient Pulse Propagation in Laminated Composites

B.R. Seymour and M.P. Mortell
Dept. of Mathematics and Inst. of Appl. Math. and Statistics, Univ. of British Columbia, Vancouver, B.C., Canada, J. Appl. Mech., Trans. ASME, 44 (4), pp 683-688 (Dec 1977) 4 figs, 10 refs

Key Words: Composites, Laminates, Transient response

The transient response of a laminated composite is treated. The effects of quadratic and cubic nonlinearity in the stress-strain law and reflections at interfaces are included.

DAMPING

(Also see Nos. 772, 892)

78-805

Experiments on the Transient Response of Oil-Film Dampers

M. Botman and R.K. Sharma
Pratt & Whitney Aircraft of Canada, Ltd., Longueil, Quebec, Canada, J. Engr. Power, Trans. ASME, 100 (1), pp 30-35 (Jan 1978) 10 figs, 2 tables, 5 refs

Key Words: Fluid-film damping, Turbomachinery, Experimental data

Oil-film dampers are used in turbomachinery to suppress undesirable shaft dynamic responses. They are located at the nonrotating outer race of selected main bearings. Experiments on the synchronous behavior of oil-film dampers under steady unbalance loads have been reported. In this paper results are presented on experiments on the transient response of dampers which are subject to simulated blade-loss loads at high speed. The tests were performed on the rig used for the synchronous tests. A method of data reduction was developed. Results are shown for a number of different masses released at various speeds and dampers with several clearances.

78-806
Efficient Means of Noise Control
J.E. Koch
Soundcoat Co., Inc., Brooklyn, NY, Diesel and Gas Turbine Progress, 44 (2), pp 38-39 (Feb 1978) 8 figs

Key Words: Noise control, Vibration damping

A damping technique is described, which makes use of a stiff constraining layer that is attached to the damping layer, so when the structure vibrates in flexure, the damping material is forced to undergo shearing strains with the resultant dissipation of vibrational energy.

FLUID

(Also see Nos. 792, 828, 831, 841, 842, 846, 857, 862)

78-807
Dynamic Response of a Containment Vessel to Fluid Pressure Pulses
F.L. DiMaggio and H.H. Bleich
Dept. of Civil Engrg. and Engrg. Mechanics, Columbia Univ., NY 10027, Intl. J. Computers and Struc., 8 (1), pp 31-39 (Feb 1978) 24 figs, 3 refs

Key Words: Containment structures, Fluid-induced excitation

Two methods, one of which is a very simple approximation, are proposed for the dynamic analysis of the response of the wall of a nuclear containment vessel to the fluid pressure exerted on it when the relief valve discharge piping is cleared.

78-808
Continuation and Direct Solution of the Flutter Equation
C.C.-P. Mantegazza
Aerospace Engrg. Inst., Polytechnic of Milan, Via Golgi 40, Milan, 20133, Italy, Computers and Struc., 8 (2), pp 185-192 (1978) 5 figs, 17 refs

Key Words: Aircraft, Flutter, Fluid-induced excitation

A continuation and a direct method for the solution of flutter stability problems is presented. The continuation method permits an easy and efficient tracking of the aeroelastic modes, frequencies and approximate damping. Some practical examples are presented and discussed.

78-809
Aerodynamic Interference in a System of Two Harmonically Oscillating Airfoils and its Influence on Flutter
J. Grzedzinski
Polish Academy of Sciences, Warsaw, Poland, 113 pp (Jan 21, 1977)
(In Polish)
N78-10016

Key Words: Flutter, Airfoils, Aerodynamic stability

A two-dimensional model which can provide a determination of the critical flutter speed in a system of two mutually interacting airfoils was employed. The basic characteristic of interference was taken into account, namely, the effect of whirling wakes arising behind the airfoils. Results of various experiments are presented.

78-810
Experimentally Determined Stability Parameters of a Subsonic Cascade Oscillating Near Stall
F.O. Carta and A.O. St. Hilaire
United Technologies Res. Center, East Hartford, CT, J. Engr. Power, Trans. ASME, 100 (1), pp 111-120 (Jan 1978) 18 figs, 1 table, 8 refs

Key Words: Blades, Aerodynamic stability, Airfoils, Fluid-induced excitation

Tests were performed on a linear cascade of airfoils oscillating in pitch about their midchords at frequencies up to 17 Hz at free-stream velocities up to 200 ft/s, and at interblade phase angles of 0 deg and 45 deg, under conditions of high aerodynamic loading. The measured data included unsteady time histories from chordwise pressure transducers and from chordwise hot films. Unsteady normal force coefficient, moment coefficient, and aerodynamic work per cycle of oscillation were obtained.

78-811

Vibratory Forcing Functions Produced by Nonuniform Cascades

T.J. Barber and H.D. Weingold
Pratt and Whitney Aircraft, East Hartford, CT,
J. Engr. Power, Trans. ASME, 100 (1), pp 82-88 (Jan 1978) 13 figs, 6 refs

Key Words: Rotor blades, Aerodynamic excitation, Fluid-induced excitation

A method is developed to predict the steady, two-dimensional incompressible flowfield through tandem cascades or multibody cascade geometries. The technique is adapted from the classical Douglas-Neumann method, in which a superposition of singularities is used to simulate the cascade geometries. The method is used to analyze the self-induced potential field interaction of a stator cascade with a finite thickness strut cascade behind it or integral within it, such as occurs in fan ducts and intermediate cases of large gas-turbine engines. The calculation predicts the magnitude and location of the nonuniform pressure distortion, which would be imposed on an upstream engine component, for a variety of cascade designs.

78-812

Dynamics of a Neutrally Buoyant Inflatable Oceanographic Platform

A.K. Misra and V.J. Modi
The Univ. of British Columbia, Vancouver, B.C., Canada, ASME Paper No. 77-DET-139

Key Words: Floating structures, Inflatable structures, Hydrodynamic excitation

The dynamics of a flexible platform consisting of an array of three neutrally buoyant inflated tapered legs attached to a central head, connected to a surface float by a cable is studied. A general Lagrangian formulation of the problem, accounting for the hydrodynamic forces, is presented. For small oscillations, inplane and out-of-plane motions decouple and are analyzed separately.

VISCOELASTIC

(See No. 799)

EXPERIMENTATION

DATA REDUCTION

78-813

Digital Techniques in Data Analysis

L. Enochson
Time/Data Div., GenRad, Inc., 2855 Bowers Ave, Santa Clara, CA 95051, Noise Control Engr., 9 (3), pp 138-154 (Nov/Dec 1977) 24 figs, 1 table, 11 refs

Key Words: Digital techniques, Spectral energy distribution, Acoustic spectra

The techniques of digital time series data analysis are very important in solving contemporary acoustic problems. In this paper two types of functions and their implementation by modern minicomputer-based systems are discussed: spectral density functions, including power spectral density, cross-spectral density, transfer and coherence functions; and time domain functions, including crosscorrelation, impulse response, and the inverse complex coherence function. Within the first classification, pure digital and hybrid techniques for octave and one-third octave band analysis are reviewed.

DIAGNOSTICS

(See Nos. 842, 893)

EQUIPMENT

78-814

An Experimental Investigation of the Dynamic Behavior of a Roller Chain Drive

S.R. Turnbull, S.W. Nicol, and J.N. Fawcett
Univ. of Lancaster, UK, ASME Paper No. 77-DET-168

Key Words: Test equipment and instrumentation, Chains, Conveyors, Noise source identification

A test rig for investigating the dynamic behavior of roller chains by measuring sprocket accelerations is described. Four main types of vibration are identified including a high frequency vibration which occurs as a roller is removed from the chain span. This high frequency component appears to be the major source of chain noise.

FACILITIES

(See No. 821)

INSTRUMENTATION

78-815

Experimental Investigation of Performance Characteristics of Flexible Shaft Couplings

B. Eghbali and T.R. Kane
Stanford Univ., Stanford, CA., ASME Paper No. 77-DET-129

Key Words: Test equipment and instrumentation, Flexible couplings, Shaft couplings

An apparatus that can be used to investigate performance characteristics of flexible shaft couplings which permit angular misalignments is described. Experimental results for two couplings with known performance characteristics demonstrate the capabilities and the accuracy of the apparatus.

78-816

Real Time Frequency Analyzers for Noise Control

G.W. Kamperman and M. Moore
Kamperman Associates, Inc., 1110 Hickory Trail, Downers Grove, IL 60515, Noise Control Engr., 9 (3), pp 131-136 (Nov/Dec 1977) 9 figs, 10 refs

Key Words: Measuring instruments, Frequency analyzers, Noise control

The basic principles of real time frequency analyzers and some of the operating characteristics of current instruments are discussed with respect to sound and vibration signals.

78-817

Sound Level Meters: The State of the Art

W.R. Kundert
Acoustics, Vibration and Analysis Div., GenRad, Inc., Bolton, MA 01740, Noise Control Engr., 9 (3), pp 120-130 (Nov/Dec 1977) 16 figs, 9 refs

Key Words: Noise measurement, Measuring instruments, Sound level meters

Modern standards and features of sound level meters are discussed along with guidelines for use.

78-818

Measurement Microphones

G. Rasmussen
A/S Bruel & Kjaer, 2850 Naerum, Denmark, Noise Control Engr., 9 (3), pp 109-119 (Nov/Dec 1977) 18 figs, 1 table, 16 refs

Key Words: Noise measurement, Measuring instruments

Although many devices may serve as measurement microphones for a variety of applications, certain qualities are necessary to ensure accurate results. The development and characteristics of those microphones used in the general measurement of sound are traced.

78-819

A Technique for Measuring Sound Intensity with a Sound Level Meter

F.J. Fahy
Inst. of Sound and Vibration Res., Southampton Univ., Southampton S09 5NH, UK, Noise Control Engr., 9 (3), pp 155-162 (Nov/Dec 1977) 3 figs, 4 tables, 14 refs

Key Words: Sound measurement, Sound level meters, Measuring instruments

A system designed to measure acoustic intensity vector, which could be of value in diagnostic investigations involving narrow band analysis is described. The proposed method uses two standard, commercially available condenser microphones and a portable sound level meter fitted with octave band filters.

SCALING AND MODELING

(Also see Nos. 800, 824, 881)

78-820

A Dynamic Loads Scaling Methodology for Helicopter Rotors

L. Mirandy

Boeing Vertol Co., Philadelphia, PA, J. Aircraft, 15 (2), pp 106-113 (Feb 1978) 9 figs, 1 table, 2 refs

Key Words: Helicopter rotors, Scaling, Dynamic loads, Modal analysis

A method for scaling vibratory loads between dynamically dissimilar rotors is developed. It is based upon separating the blade response into contributions from each of its natural modes in order to account for dynamic differences between the model and prototype. The procedure is applied to test data obtained from different size rotors.

SIMULATORS

78-821

The Determination of Some Requirements for a Helicopter Flight Research Simulation Facility

J.B. Sinacori

Systems Technology, Inc., Mountain View, CA, Rept. No. NASA-CR-152066; TR-1097-1, 59 pp (Sept 1977)

N78-10117

Key Words: Simulators, Test facilities, Helicopters

Important requirements were defined for a flight simulation facility to support Army helicopter development. In particular, requirements associated with the visual and motion subsystems of the planned simulator were studied. The method used in motion requirements study is presented together with the underlying assumptions and a description of the supporting data. Results are given in a form suitable for use in a preliminary design.

TECHNIQUES

78-822

Noise Measurements, 1977

E.A. Starr and L.L. Beranek

Bolt Beranek and Newman, Inc., 50 Moulton St., Cambridge, MA 02138, Noise Control Engr., 9 (3), pp 100-108 (Nov/Dec 1977) 12 figs, 5 refs

Key Words: Noise measurement, Measurement techniques

The fundamentals of noise measurement are discussed. After outlining the history and rationale for these measurements, a generalized system to be used as a framework for consideration of a variety of measurements and equipment is presented. This overall approach should aid those engineers without a background in electrical engineering to better understand the functions of noise-measuring instruments.

78-823

Development of a Technique for Inflight Jet Noise Simulation -- Part I

W.S. Clapper, R. Mani, E.J. Stringas, and G. Banerian

General Electric Co., Cincinnati, OH, J. Aircraft, 15 (2), pp 85-92 (Feb 1978) 17 figs, 2 tables, 9 refs

Key Words: Jet noise, Simulation, Testing techniques

A study was conducted to identify and evaluate several inflight simulation techniques. These include closed-circuit wind tunnels, freejets, rocket sleds, and high-speed trains. The most promising technique was selected for demonstration and validation. The pertinent results from the evaluation phase and the rationale which led to the selection of the freejet simulation technique are discussed, including advantages and disadvantages.

78-824

Vibration Analysis Performed by a Combination of Holographic Interferometry and the Finite Element Technique (Schwingungsanalyse Durch Kombinierte Anwendung Der Holografischen Interferometrie und Der Berechnung Mittels Finiter Elemente)

K.-J. Schmidt and W. Kreitlow

Institut f. Mechanik, Institut f. Messtechnik im Maschinenbau, Technische Universität Hannover, West Germany, Mech. Res. and Comm., 4 (6), pp 427-434 (June 1977) 4 figs, 3 refs

(In German)

Key Words: Interferometers, Holographic techniques, Mathematical models, Vibration response

The possibility of combining holographic interferometry with numerical methods in vibration analysis is investigated. The aim of this article is to determine to what extent the holographic vibration analysis can be applied to measure the effects of parameter changes on the vibration of mechanical systems previously described by mathematical models.

78-825

Experimental Study by Radio Link-Telemetry of the Vibratory Behavior of the Blades of a Steam Turbine in Working Conditions

R. Bigret, D. Borgese, O. Bravin, G. Diana, and W. Serravalli

Alsthom-Atlantique la Courneuve, France, ASME Paper No. 77-DET-148

Key Words: Testing techniques, Radio telemetry, Turbines, Steam turbines, Turbine blades

A strain-gage equipment and telemetry measurement, enabling dynamic measurements in a 150°C (300°F) environment heavily laden with water and subjected to high acceleration, are briefly described in this paper. A data processing system is presented and discussed. The processing system makes it possible to determine the maximum strain from the data recorded during the start and power buildup of a turbine. Results are given that enable the main characteristics of the system to be established, at rest and in working condition.

HOLOGRAPHY

(See No. 824)

COMPONENTS

ABSORBERS

78-826

Impact Absorbing Blade Mounts for Variable Pitch Blades

R. Ravenhall, C.T. Salemme, and A.P. Adamson

Lewis Res. Center, NASA, Cleveland, OH, U.S. PATENT-4 047-840, 6 pp (Sept 13, 1977)

Key Words: Mountings, Blades, Propeller blades, Fans, Shock absorbers

A variable pitch blade and blade mount are reported that are suitable for propellers, fans and the like and which have improved impact resistance. Composite fan blades and blade mounting arrangements permit the blades to pivot relative to a turbine hub about an axis generally parallel to the centerline of the engine upon impact of a large foreign object, such as a bird. Centrifugal force recovery becomes the principal energy absorbing mechanism and a blade having improved impact strength is obtained.

BEAMS, STRINGS, RODS, BARS

(Also see Nos. 783, 853, 872)

78-827

Wear and Vibrational Strength Investigations on the Upper Track, Made of Ti A16 V4, of Landing Flap 4 of the A 300 B

D. Wetzel

Deutsche Forschungs- und Versuchsanstalt f. Luft- und Raumfahrt, Brunswick, West Germany, Rept. No. DLR-1B-152-77/11, 27 pp (May 24, 1977) (In German)

N78-11058

Key Words: Railroad tracks, Vibration response, Wear

Wear and vibration strength tests were made on the landing flap upper track of the European Airbus A-300 B. The rolling contact load tests are described and the results of the tests are presented.

78-828

Influence of Static and Dynamic Asymmetric Loading Conditions on Silo Design

D. Bervig, A. Wiley, and T. Sutton

Black & Veatch Consulting Engineers, Kansas City, MO, ASME Paper No. 77-DET-145

Key Words: Silos (missiles), Flow-induced excitation, Design techniques

The purpose of this paper is to help establish a reasonable approach to determining the forces resulting from asymmetric flow situations as well as showing how these asymmetric loading conditions can influence silo design.

78-829

Dynamic Stability of Fixed-Fixed and Free-Free Timoshenko Beams Resting on an Elastic Foundation

B.A.H. Abbas and J. Thomas

Univ. of Surrey, Guildford, UK, ASME Paper No. 77-DET-134

Key Words: Beams, Elastic foundation, Natural frequencies, Finite element technique, Mathematical models, Timoshenko theory

A finite element model is developed in this paper for the stability analysis of fixed-fixed and free-free Timoshenko beams resting on an elastic foundation and subjected to periodic axial loads. The effects of an elastic foundation on the natural frequencies and static buckling loads are investigated.

78-830

Effect of Axial Force on Dynamic Fracture of a Beam or Plate in Pure Bending

H. Adeli, G. Herrmann, and L.B. Freund

Div. of Applied Mechanics, Stanford Univ., Stanford, CA, J. Appl. Mech., Trans. ASME, 44 (4), pp 647-651 (Dec 1977) 3 figs, 14 refs

Key Words: Beams, Plates, Fracture properties

The dynamic fracture response of a long beam of brittle elastic material subjected to pure bending is studied. If the magnitude of the applied bending moment is increased to a critical value, a crack will propagate from the tensile side of the beam. As an extension of previous work, a dynamically induced axial force which is generated during the fracture process is included in the analysis.

BEARINGS

(See No. 892)

BLADES

(Also see Nos. 811, 825, 826)

78-831

Highly Cambered Blades, Mounted in Cascades and Oscillating in a Fluid in Transonic Flow

R. Legendre

European Space Agency, Paris, France, Rept. No. ESA-TT-408 (Engl. transl. from La Rech. Aerospatiale, Bull. Bimestriel, Paris, No. 1977-2, pp 129-130 (Mar-Apr 1977))

N78-11998

Key Words: Turbine blades, Aerodynamic excitation, Fluid induced excitation

A method is presented for calculating unsteady aerodynamic forces acting on highly cambered turbine blades mounted in a two-dimensional cascade and oscillating in the compressible fluid which crosses the cascade at transonic flow. The method is applied in particular to the calculation of the unsteady irrotational perturbations on the blades and the shock waves arising.

78-832

Study of the Vibrations of Rotating Blades

M. Swaninadham

National Aeronautical Lab., Bangalore, India, ASME Paper No. 77-DET-147

Key Words: Blades, Rotating structures, Vibration response, Rayleigh-Ritz method, Vibration tests

This paper presents the results of a study of the vibration characteristics of rotating, twisted, and tapered blades. The Rayleigh-Ritz method of solution is applied to obtain the eigenvalues. Experimental results are reported.

78-833

Research on the Flutter of Axial-Turbomachine Blading

F. Sisto and H. Tokel

Dept. of Mech. Engrg., Stevens Inst. of Tech., Hoboken, NJ, Rept. No. ME-RT-77004, 39 pp (Nov 1977)

AD-A047 086/4GA

Key Words: Turbomachinery blades, Flutter, Plates, Harmonic response

The dynamic stall of an airfoil with leading edge bubble separation is analyzed. The mathematical model representing the physical problem is presented.

78-834

Vibration Investigation of Helicopter Engine Cooling Fan

N.S. Swansson and G.A. Duke

Aeronautical Research Labs., Melbourne, Australia, Rept. No. ARL/M.E.363, 19 pp (Mar 1977)

AD-A047 081/5GA

Key Words: Blades, Fans, Cooling systems, Helicopter engines, Fatigue life, Resonant response, Shrouds

An investigation into the cause of the unacceptably high incidence of fatigue failure of blades in the engine cooling fan fitted to Sioux helicopters led to a search for resonant frequencies of the fan blades. Tests on a stationary fan and in a rotating rig showed resonant vibration at various fan speeds; in particular, high stresses were generated by a second shaft order resonance close to the normal operating speed. A modification to overcome the problem is proposed. Tests were conducted on the proposed modification and results are reported.

FRAMES, ARCHES

78-835

On the Calculation of Structures Subject to Vibration Load

P. Baublys and A. Krutinis

Vilniaus Inžinerijos ir Statybos Institutas, Vilnius, Lietuvos TSR, Lietuvos Mechanikos Rinkinys: Lietuvos TSR Aukštųjų Mokyklų Darbai, Vilnius, No. 1 (16), pp 71-80 (1976) 4 figs, 4 tables, 4 refs (In Russian)

Key Words: Framed structures, Free vibration

Some computing problems of elastic framed structures (with limited number of degrees of freedom) subjected to free vibrations and dynamic forces are considered. The proposed calculation method can be applied to any shape plane framed structure. Numerical examples of multispan beam, multistory frame and truss are presented.

78-836

Optimal Seismic Design of Plane Frames

M.E. Botkin

Black and Veatch Consulting Engineers, Kansas City, MO, ASME Paper No. 77-DET-137

Key Words: Frames, Seismic design

A method is presented for the design of frameworks subjected to earthquake type loadings. Various considerations for rigid frame design include damping, the P-Δ effect, and the combination with gravity type loadings are addressed. Base excited accelerations are provided through the use of the Nuclear Regulatory Commission Guide 1.60 response spectra curves.

GEARS

78-837

The Spring of the Ring

A.I. Tucker

Solar Div., International Harvester, San Diego, CA, ASME Paper No. 77-DET-125

Key Words: Gears, Rings

Ring gears are used in epicyclic gear arrangements. In a star arrangement the ring gear is a rotating member. A rotating ring has appreciable deflections caused by tooth loads and by forcing functions of various frequencies. These deflections affect the tooth mesh. In addition, the ring must be designed so that its natural frequency does not coincide with a multitude of forcing functions. Methods to avoid problems caused by these phenomena are discussed in this paper.

78-838

An Experimental and Theoretical Study of the Effects of Simulated Pitch Line Pitting on the Vibration of a Geared System

M.J. Drosjack and D.R. Houser

Shell Oil Co., Houston, TX, ASME Paper No. 77-DET-123

Key Words: Gears, Vibration response, Mathematical models

This paper presents the development of a gear dynamics model which has the capability to simulate gear tooth faults and present both time and frequency domain responses of the system. Results of experiments indicate that the model predicts similar phenomena to those obtained experimentally.

MECHANICAL

78-839

Synthesis of Eccentric Slider-Crank Mechanism by Optimizing the Functions of Friction Forces in Kinematic Couples

S. Stravinskas

Kauno Polytechnikos Institutas, Kaunas, LTSR, Lietuvos Mechanikos Rinkinys: Lietuvos TSR Aukštųjų Mokyklų Darbai, Vilnius, No. 1 (16), pp 11-17 (1976) 2 figs, 2 refs
(In Russian)

Key Words: Structural synthesis, Slider crank mechanisms

The synthesis of an eccentric slider-crank mechanism is discussed taking the least friction force powers in the rotary kinematic couples of the connecting rod and the sliding kinematic couple of the slider as optimum criteria.

78-840

Prediction of Noise Aerodynamically Generated by Control Valves

N. Mirizzi, R. Stella, and D. Marino

Universita di Bari, Bari, Italy, ISA Trans., 16 (4), pp 19-22 (1977) 3 figs, 6 refs

Key Words: Valves, Noise generation, Noise prediction

An analysis of control valve noise is developed. The total sound pressure level (SPL) aerodynamically generated by the fluid flow through the control valves is considered. In this analysis the noise generated is assumed to be part of the mechanical power lost from the inlet to the outlet section of a valve.

PIPES AND TUBES

78-841

Response of a Tube Bank to Turbulent Crossflow Induced Excitation

B.T. Lubin

Combustion Engineering, Windsor, CT, ASME Paper No. 77-DET-142

Key Words: Tubes, Fluid-induced excitation

Results are presented for the amplitude response of the central tube in a staggered array, subjected to crossflow. The Reynolds number range, based on tube diameter and approach velocity, was from 2×10^5 to 2×10^6. Analysis of PSD plots of the response indicate that at low flows the forcing mechanism is related to far field effects while at higher flows the near field (turbulent buffeting related) loads dominate.

78-842

Fluid Forces in Real Heat Exchanger Tube Vibrations

W.G. Perera

Perera and Associates, London, UK, ASME Paper No. 77-DET-146

Key Words: Tubes, Heat exchangers, Fluid-induced excitation, Damage prediction

Most real heat exchangers have been observed to fail at the tube rows closest to the baffle cut. Analysis of this area is undertaken starting from the equations of motion, and emphasis is placed on fluid forces. In particular, dynamic buoyancy effects and the accompanying mean stresses are shown important for proper damage prediction.

78-843

Dynamic Analysis of Piping Systems Using Substructures

A.K. Singh and V. Kumar

Sargent & Lundy Engineers, Chicago, IL, ASME Paper No. 77-DET-144

Key Words: Piping systems, Earthquake response

This paper presents a substructure approach to compute the vibration modes of piping systems and their response to earthquake excitations. In this approach, the piping system is considered to be an assemblage of subsystems or substructures. A truncated set of the subsystem vibration modes and the dynamic degrees of freedom at the interface nodes are used to compute the vibration modes of the complete piping system. Numerical examples for two typical piping systems are presented and the influence of truncation on the final vibration modes and their seismic response is evaluated.

PLATES AND SHELLS

(Also see Nos. 783, 830, 872)

78-844

Traveling Loads on Viscoelastic Plates on Nonlinear Foundations

J. Padovan

Dept. of Mech. Engrg., Univ. of Akron, Akron, OH, J. Appl. Mech., Trans. ASME, 44 (4), pp 677-682 (Dec 1977) 6 figs, 8 refs

Key Words: Plates, Viscoelastic properties, Moving loads

Within the framework of Kirchhoff-type prestressed plate theory, the steady-state response of a viscoelastic plate strip on a nonlinear dissipative foundation to the action of general traveling loads is considered. A modified perturbation procedure is employed to solve the problem. Employing the solution, the results of several numerical experiments are presented. These emphasize the effects of dissipation, foundation nonlinearity as well as the action of periodic traveling loads.

78-845

Application of Dynamic Relaxation to the Large Deflection Elasto-Plastic Analysis of Plates

P.A. Frieze, R.E. Hobbs, and P.J. Dowling

Civil Engrg. Dept., Imperial College, London, UK, Computers and Struc., 8 (2), pp 301-310 (1978) 4 figs, 24 refs

Key Words: Plates, Elastoplastic properties, Dynamic relaxation, Finite difference theory, Iteration

The application of dynamic relaxation, a finite difference based iterative analysis, to the study of plates to date is reviewed. The extension of the method to include both geometrical and material non-linear effects in plates is then described in detail. Particular attention is paid to aspects of the iteration parameters which control convergence. The advantages of interfacing finite difference meshes is discussed and the mesh refinement necessary for the accurate analysis of plates in compression and in shear is considered.

78-846

The Plane Hydrodynamic Problem of Oscillating Plate

V. Kargaudas

Kauno Polytechnikos Institutas, Kaunas, Lietuvos TSR, Lietuvos Mechanikos Rinkinys: Lietuvos TSR Aukštųjų Mokyklų Darbai, Vilnius, No. 1 (16), pp 30-37 (1976) 2 figs, 6 refs

(In Russian)

Key Words: Plates, Fluid-induced excitation

Pressure of perfect incompressible fluid on an oscillating plate is obtained when the plate is oscillating by any given form. The fluid is moving in any simply connected region limited by free surfaces and perfectly rigid bodies. Solution of the problem is obtained from integrals and infinite series.

78-847

A Control of Natural Frequencies of a Plate by Varying its Thickness Function by the Perturbation Method

R. Nogis

Vilniaus Inžinerijos ir Statybos Institutas, Vilnius, Lietuvos TSR, Lietuvos Mechanikos Rinkinys: Lietuvos TSR Aukštųjų Mikyklų Darbai, Vilnius, No. 1 (16), pp 24-29 (1976) 8 refs

(In Russian)

Key Words: Plates, Variable thickness, Free vibration, Vibration control, Perturbation theory

The dependence of an increment of a plate thickness function on the variation of a desirable set of the natural frequencies and mass quantity is presented. The available maximum of variation is estimated. Relations to existing formulations of optimization problems of vibrating plates are discussed.

78-848

Free Vibration of Thin Rectangular Plates by a Mixed Element

J.N. Reddy and C.-S. Tsay

Univ. of Oklahoma, Norman, OK, ASME Paper No. 77-DET-143

Key Words: Rectangular plates, Free vibration, Finite element technique

Linear and quadratic rectangular elements based on a Reissner type variational statement of thin plate bending are applied to free vibration of plates. These elements are algebraically simple and yield better accuracies when compared with other finite elements. These elements are applied to compute natural frequencies of rectangular plates with various edge conditions.

78-849

Forced Response of Stiffened Plates

R.W. Belkune and C.K. Ramesh

Indian Inst. of Tech., Bombay, India, ASME Paper No. 77-DET-150

Key Words: Stiffened plates, Forced vibration, Finite element technique

Stiffened plates with bridge-type boundary conditions and subjected to a moving constant force, or an unsprung or sprung mass, are evaluated for their forced response using a finite-element displacement formulation. A step-by-step numerical integration to generate the time-histories of the response quantities is used. The effects of variation of the essential bridge-vehicle parameters on the response of the system are comprehensively examined.

78-850

Finite Element Equivalent of the Spherical Shell

R. Karkauskas and J. Atkočiūnas

Lietuvos Mechanikos Rinkinys: Lietuvos TSR Aukštųjų Mokyklų Darbai, Vilnius, No. 1 (16), pp 91-103 (1976) 5 figs, 9 refs

(In Russian)

Key Words: Spherical shells, Finite element technique

Application of the finite element method to the analysis of shallow spherical shells is under consideration. The proposed technique is useful in the design of shells under static loading and repeated loading.

78-851

Vibration of Thin Cylindrical Shells Based on a Mixed Finite Element Formulation

W. Altman and M.N. Bismarck-Nasr

Instituto Technologico de Aeronautica, 12200 S. Jose dos Campos, SP, Brasil, Computer and Struc., 8 (2), pp 217-221 (1978) 2 figs, 2 tables, 15 refs

Key Words: Cylindrical shells, Vibration response, Finite element technique, Variational methods

A Hellinger-Reissner functional for thin circular cylindrical shells is presented. A mixed finite element formulation is developed from this functional, which is free from line integrals and relaxed continuity terms. This element is applied to the problem of vibration of rectangular cylindrical shells.

RINGS

(See No. 837)

78-852

The Forced Vibration of a Three-Layer Damped Circular Ring

F.C. Nelson and D.F. Sullivan

Tufts Univ., Medford, MA, ASME Paper No. 77-DET-154

Key Words: Circular rings, Damped structures, Forced vibration

In this paper, the equations which govern the forced vibration of a damped, three-layer circular ring segment are solved by the method of damped forced modes. The numerical behavior of the solution is studied for the case of a complete ring and design guidelines are presented.

TIRES

(See No. 861)

SYSTEMS

ABSORBER

78-853

Beamlike Dynamic Vibration Absorbers

J.C. Snowdon and M.A. Nobile

The Pennsylvania State Univ., University Park, PA, ASME Paper No. 77-DET-176

Key Words: Dynamic vibration absorption (equipment), Beams, Bernoulli-Euler method

The performance of several beamlike dynamic vibration absorbers is analyzed and, in one case, confirmed by experiment. The dynamic absorbers are employed to suppress the transmissibility at resonance across a simple mass-spring vibrator, a stanchion, and a simply supported rectangular panel. In several of the situations analyzed, transmissibility curves are calculated to emphasize that the beamlike absorbers are broadly effective.

78-854

Producing 'Soft' Exterior Parts

Auto. Engr., 85 (1), pp 52-55 (Jan 1977) 4 figs

Key Words: Energy absorption, Bumpers

The need to combine function and appearance in "soft" exterior automobile parts is rapidly advancing the use of EPDM elastomers. Their role in energy absorption is discussed.

NOISE REDUCTION

(Also see Nos. 806, 816, 884)

78-855

Vibration and Noise Reduction of Beams and Plates by Use of Boundary Damping and Stiffness

L.L. Faulkner and J.F. Hamilton

The Ohio State Univ., Columbus, OH, ASME Paper No. 77-DET-155

Key Words: Beams, Plates, Vibration control, Noise reduction, Enclosures

A solution is presented for the vibrational response of beams and plates with boundary constraints consisting of rotational springs and damping. The resulting formulation provides for the determination of the free or forced vibrational response and an evaluation of the sound radiation from vibrating structures for enclosures or machinery covers. The noise reduction of plates with compliant boundary supports is presented.

78-856

Acoustical Properties of Materials and Muffler Configurations for the 80 by 120 Foot Wind Tunnel

T.D. Scharton and M.D. Sneddon

Bolt Beranek and Newman, Inc., Cambridge, MA, Rept. No. NASA-CR-152065; Rept-3563, 70 pp (Aug 25, 1977)

N78-10116

Key Words: Mufflers, Acoustic impedance, Testing technique

Techniques for measuring the impedance of the muffler configurations and of porous plates with grazing flow were investigated and changes in the configuration parameters to enhance acoustic performance are explored. The feasibility of a pulse reflection technique for measuring the impedance of built-up structures in situ was demonstrated. A second technique involving the use of an open-end impedance tube with grazing flow was used to obtain detailed design data for the perforated plate configuration. Acoustic benefits associated with configuration changes such as curving the baffles, spacing and staggering baffle partitions, and techniques for alleviating baffle self-generated noise are described.

ACTIVE ISOLATION

78-857

Unsteady Aerodynamic Modeling and Active Aeroelastic Control

J.W. Edwards

Dept. of Aeronautics and Astronautics, Stanford Univ., CA, Rept. No. NASA-CR-148019; SUDAAR-504, 207 pp (Feb 1977)

N78-10017

Key Words: Active flutter control, Mathematical models, Aerodynamic characteristics, Airfoils

Unsteady aerodynamic modeling techniques are developed and applied to the study of active control of elastic vehicles. The problem of active control of a supercritical flutter mode poses a definite design goal stability, and is treated in detail. Exact root loci of aeroelastic modes are calculated, providing quantitative information regarding subcritical and supercritical flutter conditions.

78-858

Design of a Hardware Observer for Active Machine Tool Control

E.E. Mitchell and E. Harrison

Weapons and System Engrg. Dept., U.S. Naval Academy, Annapolis, MD, J. Dyn. Syst., Meas. and Control, Trans. ASME, 99 (4), pp 227-232 (Dec 1977) 8 figs, 18 refs

Key Words: Active isolation, Machine tools, Chatter, Forced vibration

Observer theory is applied to design an active controller for a machine tool such as a lathe to reduce the chatter tendency and forced vibration effects that can be detrimental to a workpiece surface finish. The estimated motion is used in conjunction with measured states in a second application of observer theory to design a control system that causes the cutting tool to track the workpiece, negating relative vibratory motion. Hence, the entire control system with the cutting tool position as an output is an observer of workpiece motion. Stability of the controlled system as a function of mismeasurements of dynamical parameters and its ability to reduce forced vibration effects are discussed.

AIRCRAFT

(Also see Nos. 779, 793, 808)

78-859

F-16 Flutter Model Studies with External Wing Stores

J.T. Foughner, Jr., and C.T. Bensinger

Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TM-74078, 17 pp (Oct 1977)

N78-11004

Key Words: Aircraft, Flutter, Wing stores, Model testing (testing of models)

Results from transonic flutter model studies are presented. The flutter model was constructed to support the flutter prevention and clearance program from preliminary design through flight flutter tests. The model tests were conducted

in the Langley transonic dynamics tunnel.

78-860
Elimination of a Resonant Fatigue Problem for Major Maintenance Benefits
J.D. Sharp and M.L. Drake
Wright-Patterson Air Force Base, Dayton, OH, ASME Paper No. 77-DET-135

Key Words: Aerial rudders, Fatigue life, Resonant response

The Air Force Materials Laboratory initiated a program to design an additive damping treatment which would prevent high cycle fatigue cracking in the fairing and that could be applied without disassembling the rudder from the aircraft. This program, which was initiated to avoid damage in rudder structure and save maintenance costs, is described.

78-861
Experimental and Analytical Determination of Characteristics Affecting Light Aircraft Landing-Gear Dynamics
E.L. Fasanella, J.R. McGehee, and M.S. Pappas
Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TM-X-3561; L-11472, 46 pp (Nov 1977)
N78-11052

Key Words: Landing gear, Tire characteristics

An experimental and analytical investigation was conducted to determine which characteristics of a light aircraft landing gear influence gear dynamic behavior. The investigation focused on possible modification for load control. Pseudo-static tests were conducted to determine the gear fore- and -aft spring constant, axial friction as a function of drag load, brake pressure-torque characteristics, and tire force-deflection characteristics.

BRIDGES

78-862
On the Flutter Instability of a Suspension Bridge Using the Finite Element Method
G. Diana, M. Gasparetto, and M. Falco
Polytecnic of Milan, Italy, ASME Paper No. 77-DET-140

Key Words: Suspension bridges, Flutter, Wind-induced excitation, Mathematical models, Finite element technique

The study of aeroelastic instability is fundamental for the feasibility of a large span suspension bridge. The determination of the flutter wind velocity is generally determined by a two-degree-of-freedom model. In this paper an analytical model is developed to predict the flutter behavior of a suspension bridge, with a multidegree-of-freedom system. A finite element technique is employed. The numerical difficulties related to the solution of the problem are discussed. A suitable method is developed to increase the numerical stability of the solution.

BUILDING

(Also see Nos. 780, 781, 782, 788, 868)

78-863
Concorde Noise-Induced Building Vibrations: International Airport ...ies
W.H. Mayes, H.F. Scholl, D.G. Stephens, B.G. Holliday, R. DeLoach, T.D. Finley, H.K. Holmes, R.B. Lewis, and J.W. Lynch
Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TM-74083, 19 pp (Sept 1977)
N78-10839

Key Words: Buildings, Vibration response, Acoustic excitation, Aircraft noise

A series of studies were conducted to assess the noise-induced building vibrations associated with Concorde operations. The vibration levels of windows, walls, and floors were measured along with the associated noise levels of Concorde, subsonic aircraft and some nonaircraft events.

78-864
A Methodology for Seismic Evaluation of Existing Multistory Residential Buildings. Volume 1. Methodology
C.W. Pinkham and G.C. Hart
Barnes (S.B.) and Associates, Los Angeles, CA, Rept. No. HUD/RES-1199, 96 pp (June 1977)
PB-274 609/7GA

Key Words: Multistory buildings, Earthquake resistant structures, Standards and codes

This manual describes a method of structural analysis, design and analysis of costs for the determination of strengthening of existing multi-story residential buildings to conform to the basic earthquake force requirements of the 1973 Uniform Building Code. The report is presented in three

volumes, namely, Volume I - Methodology, Volume II - Computer Users' Manual, and Volume III - Examples.

78-865

A Methodology for Seismic Evaluation of Existing Multistory Residential Buildings. Volume 3. Examples

C.W. Pinkham and G.C. Hart
Barnes (S.B.) and Associates, Los Angeles, CA, Rept. No. HUD/RES-1201, 639 pp (June 1977)
PB-274 611/3GA

Key Words: Multistory buildings, Earthquake resistant structures, Standards and codes, Computer-aided techniques

This manual describes a method of structural analysis, design and analysis of costs for the determination of strengthening of existing multi-story residential buildings to conform to the basic earthquake force requirements of the 1973 Uniform Building Code. The report is presented in three volumes. The examples in Volume III illustrate both simplified and more complex evaluation of stress distribution in different types of multi-story residences.

CONSTRUCTION

78-866

Torque, Torsional Oscillation and Deflection Analysis of Gearboxes for a 2750 Tonne Dragline

C.D. Norman and R. Clark
Queensland Inst. of Technology, Inst. of Mech. Engr., Australia, Mech. Engrg. Trans., ME2, pp 36-42 (1977) 8 figs, 1 ref

Key Words: Mining equipment, Hoists, Gear boxes, Torque, Torsional vibration

Gearboxes lifting and moving a 2750 tonne dragline required frequent maintenance. The actual input torque on the rotating shaft, R.P.M., motor volts, motor amps, and the gearbox wall deflections were unknown. Instrumentation was chosen to allow all six items to be continuously and simultaneously recorded and compared over a number of 'walking' cycles.

FOUNDATIONS AND EARTH

(Also see No. 791)

78-867

Vibration Isolating Mountings for Machinery on Suspended Floors

J.A. Macinante and H. Simmons
National Measurement Lab. C.S.I.R.O., Inst. of Mech. Engr., Australia, Mech. Engrg. Trans., ME2, pp 27-35 (1977) 8 figs, 1 table, 24 refs

Key Words: Machine foundations, Vibration isolation, Mathematical models

A suspended floor is represented as a mass-spring-damper system, which supports a similar system that represents vibrating machinery on a seismic mounting. The machinery is assumed to generate a vertical sinusoidal force of amplitude P_0. An expression is derived by conventional methods for the amplitude (F_0) of the vertical sinusoidal force transmitted into the structure supporting the floor, and hence for the transmissibility ratio (TR) which is defined as the ratio F_0/P_0. The analysis considers the fundamental flexural mode of vibration of the floor, assuming vertical vibration of the machinery on its mounting. Linear elasticity and viscous damping of both floor and mounting are assumed. From computed TR values for ranges of the system parameters of interest in practice, design curves are derived for the vertical natural frequency that must be specified for a machinery mounting, on a floor of given vertical natural frequency, to ensure that a nominated (low) TR value is not exceeded.

78-868

Dynamic Response of Non-Linear Building-Foundation Systems

J. Bielak
Instituto de Ingenieria, Universidad Nacional Autonoma de Mexico, Mexico, D.F., Intl. J. Earthquake Engr. Struc. Dynam., 6 (1), pp 17-30 (Jan-Feb 1978) 9 figs, 1 table, 27 refs

Key Words: Foundations, Buildings, Interaction: soil-structure, Hysteretic damping

An analysis is made of the steady-state response of bilinear hysteretic structure supported on the surface of a visco-elastic half-space. The method of equivalent linearization is used to solve the equations of motion, and simplified approximate formulas are obtained for the fundamental resonant frequency of the system and for an effective critical damping ratio.

HELICOPTERS

(Also see No. 820)

78-869

Noise Characteristics of Eight Helicopters

H.C. True and E.J. Rickley

Systems Res. and Dev. Service, Federal Aviation Administration, Washington, D.C., Rept. No. AD-A043842; ARD-550; FAA-RD-77-94, 169 pp (July 1977)

N78-11799

Key Words: Helicopters, Noise generation

Bell 47G, 206L, and 212 (UHIN), the Hughes 300C and 500C, the Sikorsky S-61 (SH-3B) and S-64 (CH-54B), and the Vertol CH-47C helicopters were tested to determine noise characteristics during level flyovers, simulated approaches, and hover to acquire a data base for possible helicopter noise regulatory action. The acoustic data is presented as an effective perceived noise level. A-weighted sound pressure level and 1/3 octave band sound pressure level with a slow meter characteristic per FAR Part 36. Selected waveforms and narrow band spectra are also shown. Proposed methods to quantify impulsive noise ('blade-slap') are evaluated for a level flyover for each of the helicopters.

HUMAN

(See No. 798)

ISOLATION

(Also see No. 877)

78-870

Magnetic Suspension and Pointing System

W.W. Anderson and N.J. Groom

Langley Res. Center, NASA, Langley Station, VA, PAT-APPL-807 703/GA, 10 pp (June 1977)

Key Words: Vibration isolators, Magnetic properties, Instrumentation

An apparatus is described for providing accurate pointing of instruments on a carrier vehicle and for providing isolation of the instruments from the vehicle's motion disturbances.

MECHANICAL

78-871

Optimization of a Nonlinear Torsional Mechanical System

Y.P. Kakad and J. Mahig

The Univ. of North Carolina, Charlotte, NC, ASME Paper No. 77-DET-107

Key Words: Torsional vibration, Mechanical systems

This paper deals with the original design parameters of a nonlinear torsional mechanical system which are to be modified to achieve a predetermined level of torsional oscillations under steady-state conditions. This design change is achieved through adjustment of the existing set of design parameters by means of a differential synthesis technique.

78-872

Vibrations of Beams and Plates with Edges Elastically Restrained Against Rotation Carrying Elastically Mounted Masses

P.A.A. Laura, L.E. Luisoni, and D.S. Steinberg

Inst. of Applied Mechanics, Argentina, ASME Paper No. 77-DET-87

Key Words: Coupled response, Mechanical systems, Engines, Motors, Mountings, Structural components, Beams, Plates

The present paper deals with a simple method to calculate the two lowest frequencies of coupled structural mechanical systems.

METAL WORKING AND FORMING

(Also see Nos. 773, 858)

78-873

Reliability Analysis of Machine Tool Structures

S.S. Rao and C.P. Reddy

Dept. of Mech. Engrg., Indian Inst. of Tech., Kanpur, India, J. Engr. Indus., Trans. ASME, 99 (4), pp 882-888 (Nov 1977) 7 figs, 2 tables, 13 refs

Key Words: Machine tools, Reliability, Mathematical models, Finite displacement method

A method of estimating the reliability of machine tool structures is developed. The reliability analysis of horizontal milling machines in various failure modes, like static deflection, fundamental natural frequency and chatter stability, is considered for illustration. The table height, distance of the cutter center from the arbor support, damping factor, Young's modulus of the material and the load acting on the cutter and the table are considered as random variables.

PACKAGE

(See No. 878)

PUMPS, TURBINES, FANS, COMPRESSORS

(Also see Nos. 790, 825, 826)

78-874

The Space Shuttle Main Engine High-Pressure Fuel Turbopump Rotordynamic Instability Problem

D.W. Childs

Speed Scientific School, The Univ. of Louisville, Louisville, KY, J. Engr. Power, Trans. ASME, 100 (1), pp 48-57 (Jan 1978) 13 figs, 14 refs

Key Words: Rotors, Pumps, Turbine components, Space shuttles, Whirling

The SSME (Space Shuttle Main Engine) HPFTP (High-Pressure Fuel Turbopump) has been subject to a rotordynamic instability problem, characterized by large and damaging subsynchronous whirling motion. The original design of the HPFTP (from a rotordynamic viewpoint) and the evolution of the HPFTP subsynchronous whirl problem are reviewed. The models and analysis which have been developed and utilized to explain the HPFTP instability and improve its stability performance are also reviewed.

RAIL

(Also see Nos. 795, 796, 797, 827)

78-875

Periodic Motion of Vehicles on Flexible Guideways

A.L. Doran and D.L. Mingori

Hughes Aircraft Co., Canoga Park, CA., J. Dyn. Syst., Meas. and Control, Trans. ASME, 99 (4), pp 268-276 (Dec 1977) 8 figs, 13 refs

Key Words: Interaction: vehicle-guideway, Periodic response, Ride dynamics

Periodic motions of vehicles on flexible guideways are explored as candidate "test" motions for optimization studies where it is necessary to compare large numbers of designs under equivalent conditions. Exact and approximate methods are developed for identifying initial conditions that lead to periodic motions of single vehicles or many equally spaced vehicles.

78-876

Wheel/Rail Vertical Forces in High-Speed Railway Operation

R.W. Radford

Canadian National Railways, Montreal, Quebec, Canada, J. Engr. Indus., Trans. ASME, 99 (4), pp 849-858 (Nov 1977) 22 figs, 3 tables, 2 refs

Key Words: Interaction: rail-wheel, Rail transportation, High speed transportation systems

The nature and magnitude of the vertical forces between a railway vehicle wheel and the rail at a dipped rail joint is investigated using methods developed by British Rail. The dependence of these forces on the unsprung weight is determined and a procedure is given for the specification of new equipment to insure that the principal wheel/rail forces at higher speeds will not exceed those of a reference vehicle at conventional speeds.

78-877

Passive Suspension Design for a Magnetically Levitated Vehicle

P.R. Belanger and R. Guillemette

Dept. of Electrical Engrg., McGill Univ., Montreal, Canada, J. Dyn. Syst., Meas. and Control, Trans. ASME, 99 (4), pp 277-282 (Dec 1977) 7 figs, 3 tables, 16 refs

Key Words: Ground effect machines, Suspension systems (vehicles)

This paper presents a passive suspension designed to stabilize a magnetically-levitated vehicle, using both vertical and lateral suspension elements. Response to disturbances due to guideway roughness and wind are considered.

78-878

Dynamic Simulation of Freight Car and Lading During Impact

P.V. Kasbekar, V.K. Garg, and G.C. Martin

Dynamics Research, Association of American Railroads, Chicago, IL, J. Engr. Indus., Trans. ASME, 99 (4), pp 859-866 (Nov 1977) 21 figs, 1 table, 12 refs

Key Words: Rail transportation, Freight cars, Impact response (mechanical), Mathematical models, Packaging materials

A dynamic analysis is presented to explain damage to railroad cars and ladings resulting from impacts. In the analysis,

a mathematical model consisting of the car body and freight in the car is presented. A parametric study is made to establish sensitivity of car parameters and impact conditions. The study should be useful to aid in finding means for controlling impact damage and in designing packaging materials.

78-879

Effect of Track Geometry and Rail Vehicle Suspension on Passenger Comfort in Curves and Transitions

G.R. Doyle, Jr. and M.A. Thomet

Battelle's Columbus Laboratories, Columbus, OH, J. Engr. Indus., Trans. ASME, 99 (4), pp 841-848 (Nov 1977) 8 figs, 3 tables, 16 refs

Key Words: Rail transportation, High speed transportation systems, Railroad tracks, Railroad cars, Suspension systems (vehicles), Ride dynamics, Cornering effects

The effect of track geometry and vehicle suspension characteristics on passenger comfort were investigated with a time domain simulation of the car body dynamics. The rail vehicle was simulated at constant speed on transitions and curves to generate acceleration profiles at a passenger's seat location.

78-880

Wheelset Lateral Dynamic Analysis Using the Describing Function Technique

D.P. Garg

Duke Univ., Durham, NC, ASME Paper No. 77-DET-149

Key Words: Wheelset, Railroad cars, Lateral vibration, Critical speed

This paper deals with the analysis and dynamic modeling of railway wheelsets moving on straight regular tracks. The describing function method of analysis is applied to investigate the influence of parametric variations on wheelset critical velocity. In addition, the relationship between the amplitude of sustained lateral oscillations and critical speed is derived.

REACTORS

78-881

Seismic Response of a Block Type Nuclear Reactor Core

J.G. Bennett, R.C. Dove, and J.L. Merson

Los Alamos Scientific Lab., Los Alamos, NM, ASME Paper No. 77-DET-138

Key Words: Nuclear reactors, Seismic response, Scaling

An analytical model is described that was developed to predict seismic response of large gas-cooled reactor cores. The model is used to investigate scaling laws involved in the design of physical models of such cores, and to make parameter studies.

78-882

Forced Vibration Testing of a Nuclear Fuel Assembly

K.H. Haslinger

Combustion Engineering, Inc., Windsor, CT, ASME Paper No. 77-DET-141

Key Words: Nuclear fuel elements, Forced vibration, Vibration tests, Nuclear reactor containment

A description of the test performed to determine the nonlinear dynamic characteristics of a full-size nuclear fuel assembly is presented. The parametric type of test results from this forced vibration test include the four lower lateral natural frequencies and their associated mode shapes, modal critical damping ratios and magnification factors as determined over a wide range of excitation.

RECIPROCATING MACHINE

78-833

Vibrations and Vibrationless Rotation-Reciprocation Internally Geared Device, and on Vibrationless Chain Saw Utilizing This Device

K. Ishida and T. Matsuda

Fukui Inst. of Tech., Japan, ASME Paper No. 77-DET-157

Key Words: Chain drives, Saws, Vibration control

This paper presents the theories and experiments on vibrationless rotation-reciprocation internally geared device, and on a new vibrationless chain saw utilizing this device in place of the known slider-crank device. The basic theories, constructions and experiments on perfectly or approximately balanced, rotation-reciprocation internally geared device are presented.

78-884

Investigation into the Noise Sources in a Portable Diesel Generator

W.R. Funnell and J.T. Stansfeld
Dept. of Mech. Engrg., Bristol Univ., UK, Rept. No. BU-77/B.2, 45 pp (June 1977)
N78-11803

Key Words: Diesel engines, Noise source identification, Noise reduction

An analysis of major noise producing sources from the diesel generator is presented. Methods for reducing low and middle frequencies by use of a large resonant silencer, and middle to high frequencies by use of an acoustic enclosure are described.

ROAD

(Also see No. 800)

78-885

An Analytical and Experimental Study of Automobile Dynamics with Random Roadway Inputs

A.J. Healey, E. Nathman, and C.C. Smith
Dept. of Mech. Engrg., The Univ. of Texas, Austin, TX, J. Dyn. Syst., Meas. and Control, Trans. ASME, 99 (4), pp 284-292 (Dec 1977) 9 figs, 19 refs
Sponsored by the U.S. Dept. of Transportation, Univ. Res. Program

Key Words: Interaction: vehicle-terrain, Automobiles, Road roughness, Random excitation, Ride dynamics

This paper presents the results of an analytical and experimental study of ride vibrations in an automobile over roads of various degrees of roughness. Roadway roughness inputs were measured. Three different linear mathematical models were employed to predict the acceleration response of the vehicle body.

78-886

Noncontact Nondestructive Determination of Pavement Deflection under Moving Loads

M.E. Harr and N.T. Ng-A-Qui
Air Force Civil Engrg. Center, Tyndall AFB, FL, Rept. No. FAA-RD-77-127, 327 pp (Aug 1977)
AD-A047 161/5GA

Key Words: Pavements, Runways, Moving loads, Nondestructive tests

This report presents a procedure for nondestructively evaluating and predicting the deflection response of various flexible pavements to loads imposed by different aircraft.

78-887

Determining Stiffness Coefficients and Elastic Moduli of Pavement Materials from Dynamic Deflections

C.H. Michalak, D.Y. Lu, and G.W. Turman
Texas Transportation Inst., College Station, TX, Rept. No. TT1-2-8-75-207-1, FHWA/RD-77-S0665, 114 pp (Nov 1976)
Sponsored by the Texas State Dept. of Highways and Public Transportation, Austin, TX
PB-274 239/3GA

Key Words: Pavements, Modulus of elasticity, Stiffness coefficients, Computer programs

Several methods of computing stiffness coefficients or elastic moduli of materials to be used in computerized pavement design procedures are presented in this report. The methods include computer codes for calculating stiffness coefficients and elastic moduli of simple two-layer pavement structures, a graphical technique of obtaining elastic moduli of simple two-layer pavement structures, and two recently developed computer codes for calculating stiffness coefficients of multi-layer pavement structures. The method of solution and the basic equations of each method are presented.

78-888

Contribution to the Steering Performance of Passenger Cars (Bietrag zum Lenkverhalten von Personenwagen)

F. Vlk
Automobiltech. Z., 79 (12), pp 587-591 (Dec 1977) 7 figs, 1 table, 13 refs

Key Words: Frequency response method, Passenger vehicles

Frequency response is useful to demonstrate the transfer functions of vehicle systems. The frequency responses of yaw rate, roll angle, and lateral acceleration to a sinusoidal input at the steering wheel are measured. The results of the vehicle tests are compared to theoretical results, obtained by simulation of a linear vehicle model.

78-889

Steer Step Input and Transient Response of Motor Vehicles (Lenkwinkel-Sprung und Übergangsverhalten von Kraftfahrzeugen)

E. Bisimis, H.-D. Beckmann, R. Rönitz, and A. Zomotor

Automobiltech. Z., 79 (12), pp 577-580, 583-586 (Dec 1977) 14 figs, 20 refs

Key Words: Transient response, Motor vehicles

This paper describes measurements, evaluation and interpretation of transient response behavior of motor vehicles excited by step steer inputs.

ROTORS

(Also see Nos. 769, 820)

78-890

Splitter-Bladed Centrifugal Compressor Impeller Designed for Automotive Gas Turbine Application

R.C. Pampreen

Chrysler Corp., Detroit, MI, Rept. No. NASA-CR-135237, 44 pp (June 1977)

N78-10472

Key Words: Impellers, Compressor impellers, Rotors, Design techniques

Mechanical design and fabrication of two splitter-bladed centrifugal compressor impellers were completed for rig testing at NASA Lewis Research Center. These impellers were designed for automotive gas turbine application.

78-891

Design of Rotors for Improved Structural Life

J.T. Hill

Commercial Products Div., Pratt and Whitney Aircraft Group, East Hartford, CT, In: MIT An Assessment of Technol. for Turbojet Engine Rotor Failures, pp 331-346 (Mar 1977)

N78-10085

Key Words: Rotors, Dynamic analysis, Design techniques

Major rotor design criteria are discussed with particular emphasis on those aspects of rotor design that ensure long life component integrity. Dynamic considerations that necessitate tuning of bladed disk and seal assemblies to avoid excessive vibratory stress at both design and off-design conditions are reviewed as well as low cycle fatigue considerations. This resulted in detailed analysis procedures to establish part temperature and stress variation throughout an operating cycle. Extensive specimen and component fatigue testing was used to establish safe cyclic operating limits. The frequency, size, and behavior of intrinsic material defects were investigated. Manufacturing process improvements, including the application of increasingly sophisticated inspection techniques and quality control procedures are reviewed in light of their impact on component durability.

78-892

Optimum Bearing and Support Damping for Unbalance Response and Stability of Rotating Machinery

L.E. Barrett, E.J. Gunter, and P.E. Allaire

Dept. of Mech. Engrg., School of Engrg. and Applied Science, Univ. of Virginia, Charlottesville, VA, J. Engr. Power, Trans. ASME, 100 (1), pp 89-94 (Jan 1978) 6 figs, 2 tables, 14 refs

Key Words: Rotor-bearing systems, Bearings, Unbalanced mass response, Damping

This paper presents an approximate method for calculating the optimum bearing or support damping for multimass flexible rotors to minimize unbalance response and to maximize stability in the vicinity of the rotor first critical speed. The method has the advantage of being quickly and easily applied and can reduce analysis time by eliminating a time consuming search for the approximate optimum damping using more exact methods.

78-893

Rotor Burst Protection Criteria and Implications

R.B. McCormick

Boeing Commercial Airplane Co., Seattle, WA, In: MIT An Assessment of Technol. for Turbojet Engine Rotor Failures, pp 37-43 (Mar 1977)

N78-10071

Key Words: Rotors, Aircraft engines, Failure analysis

Current aircraft design practices to minimize the hazard from rotor bursts are described. The consequences of non-contained engine failures and the impact of rotor burst protection systems on aircraft design are discussed.

SPACECRAFT

(Also see No. 771)

78-894

Development of Modal Techniques Using Experimental Modal Data. End of Phase 1

A. Bertram, M. Degener, and R. Freymann

Inst. f. Aeroelastik, Deutsche Forschungs- und Versuchsanstalt f. Luft- und Raumfahrt, Göttingen, West Germany, Rept. No. DLR-1B-253-77-C-05; ESA-CR(P)-992, 72 pp (Aug 1977)
N78-11191

Key Words: Spacecraft, Modal analysis

The development of modal survey techniques for spacecraft structures was investigated. Effects of small modifications of structural configuration were studied. Analytical calculations were carried out for a two-mass oscillator, and experimental studies are reported on a wing model with external stores.

78-895

Launch Vehicle Payload Interface Response

J.C. Chen, B.K. Wada, and J.A. Garba
Jet Propulsion Lab., Pasadena, CA, J. Spacecraft and Rockets, 15 (1), pp 7-11 (Jan/Feb 1978) 4 figs, 6 refs

Key Words: Spacecraft, Launchers

A method has been developed by which an estimate of the launch vehicle/payload interface response is derived from the interface responses obtained from missions with the identical launch vehicle but different payloads. This method requires the knowledge of the launch vehicle eigenvalues, interface modal displacements, and the dynamic characteristics of the payloads.

78-896

Results of an Investigation of the Acoustic and Vibrational Environment of a Full Scale Space Shuttle Orbiter Structural Test Panel with Simulated TPS in the Ames Unitary Plan Wind Tunnel, Model 81-0, Test OS8A and B

R.B. Kingsland
Rockwell International Corp., Downey, CA., Rept. No. NASA-CR-151378; DMS-DR-2179, 609 pp (Oct 1977)
N78-11185

Key Words: Space shuttles, Acoustic tests, Vibration tests, Wind tunnel tests

Results of tests OS8A and B and pertinent test and model information are presented. The test was conducted in two parts. Test OS8A was performed in the NASA/ARC unitary 11-foot section and OS8B was conducted in the NASA/ARC unitary 9 x 7 tunnel. Test objectives were to investigate thermal protection system (TPS) tile sensitivity to extreme pressure gradients and vibration and to define the TPS aerodynamic environment.

STRUCTURAL

78-897

Dynamic Behavior of the Steam Generator and Support Structures of the 1200 MW Fossil Fuel Plant, Unit Number 3, Paradise, Kentucky

T.Y. Yang, M.I. Baig, and J.L. Bogdanoff
School of Aeronautics and Astronautics, Purdue Univ., Lafayette, IN, Rept. No. NSF/RA-760719, 69 pp (June 3, 1976)
PB-274 700/4GA

Key Words: Fossil power plants, Power plants, Seismic response

A detailed dynamic analysis, presented in a series of reports, was conducted on the seismic response and structural safety of key subsystems (steam generator, high pressure piping, coal handling equipment, cooling tower, chimney) of Unit No. 3 of TVA at Paradise, Kentucky in order to determine the natural frequencies of the key components below 50 Hz and the corresponding normal modes, determine response of plant to seismic disturbances, verify through full scale tests results obtained earlier, and determine estimates of damping, determine potential failure modes of major structural components, and determine a spare parts policy for a power system so that outages due to damage from seismic disturbances are minimal.

TRANSMISSIONS

(Also see Nos. 815, 837)

78-898

Transmission Design with Finite Element Analysis: Part 1

R.W. Howells
Boeing Vertol Co., Philadelphia, PA, Power Transm. Des., 20 (2), pp 34-38 (Feb 1978) 9 figs, 2 refs

Key Words: Power transmission systems, Finite element technique, Design techniques, Mathematical models

Finite element analysis is fast becoming a regular technique for drive designers. A transmission design tool using finite element methods is presented. A computer model of the CH-47 helicopter forward rotor transmission was developed

and applied to optimize transmission design. The current effort to minimize overall vibration and noise levels and to optimize the housing structural design is described.

78-899

On the Kinematic and Dynamic Synthesis of a Variable-Speed Drive

T.W. Lee

Rutgers Univ., New Brunswick, NJ, ASME Paper No. 77-DET-124

Key Words: Variable speed drives, Dynamic synthesis

A kinematic and dynamic synthesis variable-speed drive, namely, the "Zero-Max" drive, is presented. It involves the determination of the dimensions of the system that will minimize the required torque on the speed control arm while retaining an acceptable performance level. Kinematic-, dynamic-, and force-analysis were given in a form suitable for computer-aided design. The problem was solved as a heuristic combinatorial optimization problem.

78-900

Flat Belt Dynamics, Including Viscoelastic Effects

A. Cardou and G.V. Tordion

Laval Univ., Quebec, Canada, ASME Paper No. 77-DET-166

Key Words: Belt drives, Power transmission belts, Viscoelastic damping, Internal damping

General equations for flat belt dynamics have been derived, which show the influence of centrifugal effects in slightly different terms than the classical formulas. These equations have been applied to the case of a Kelvin-Voigt viscoelastic material, indicating in what range of the parameters internal damping could have some importance in the power transmission efficiency. A typical real belt material has been used to illustrate the theoretical results.

78-901

On the Forces Between the Belt and Driving Pulley of a Flat Belt Drive

T.C. Firbank

Univ. of Bradford, West Yorkshire, UK, ASME Paper No. 77-DET-161

Key Words: Belt drives, Power transmission belts, Pulleys, Friction, Experimental data

The circumferential and radial forces between a flat belt and a driving pulley are recorded experimentally by a special force transducer. The results show that both static and kinetic friction are involved in power transmission. An unexpected feature is the presence of a force where the belt runs onto the pulley, such that the belt drives the pulley over a part of the arc of contact.

78-902

A New Wrinkle to Diaphragm Couplings

J.R. Mancuso

Zurn Industries, Inc., Erie, PA, ASME Paper No. 77-DET-128

Key Words: Couplings, Diaphragm couplings

The development and philosophy behind the design of the multiple convoluted diaphragm coupling is presented. Specific areas discussed are the advantages of the thin multiple parallel path diaphragm and the wrinkle (convolution) and how they function with respect to angular, offset, and axial misalignment. Moments and forces of a multiple convoluted diaphragm are compared to gear tooth, diaphragm, and disk couplings.

78-903

Coupling Selection for Synchronous Motor Drive Systems

P. DeChoudhury, S.J. Zsolcsak, and E.W. Barth

Elliott Co., Jeannette, PA, ASME Paper No. 77-DET-131

Key Words: Couplings, Torsional vibrations, Motors

Torsional vibration design problems encountered during starting on typical synchronous motor-gear-compressor systems are described.

78-904

Shaft Couplings and the Cinderella Syndrome

J. Wright

Koppers Co., Inc., Baltimore, MD, ASME Paper No. 77-DET-132

Key Words: Shaft couplings

When prime mover and driven machinery are coupled together they form a drive system and dynamic forces are obtained which may be many times greater than the forces generated by the individual machines. The shaft couplings must control these forces because the main machinery is already built, or nearing completion before the system

analyses are made. To illustrate the versatility of shaft couplings with regard to the problems described, four drives have been selected for consideration: diesel-marine propulsion; turbo-compressor; steel rolling mill; and synchronous motor drives.

78-905

Dynamic Analysis of a Hydrostatic Clutch

P. Seleghim

Univ. of Sao Paulo, Brazil, ASME Paper No. 77-DET-153

Key Words: Clutches, Hydrostatic drives

The purpose of this work was to perform a dynamic analysis of the hydrostatic clutch. The hydrostatic clutch utilized was the disk type having oil pumped between the disks. The first part of the work is dedicated to the analysis of the clutch when a dynamic model was developed by writing its equations with its corresponding simplifying hypothesis.

78-906

The Trailing Shoe Type Centrifugal Clutch -- Design Principles and Characteristics

E.C. Goodling

Gilbert Associates, Inc., Reading, PA, ASME Paper No. 77-DET-126

Key Words: Clutches, Design techniques

The centrifugal clutch is often used on industrial machinery drives to minimize startup load demands on motors and to cushion shock loads on drive train components. This paper describes centrifugal clutches in general and discusses briefly some of their operating characteristics.

TURBOMACHINERY

(See No. 805)

AUTHOR INDEX

PERIODICALS SCANNED

PUBLICATION AND ADDRESS	ABBREVIATION
ACTA MECHANICA Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Acta. Mech.
ACUSTICA S. Hirzel Verlag, Postfach 347 D-700 Stuttgart 1 W. Germany	Acustica
AERONAUTICAL JOURNAL Royal Aeronautical Society 4 Hamilton Place London, W1V 0BQ, UK	Aeronaut. J.
AERONAUTICAL QUARTERLY Royal Aeronautical Society 4 Hamilton Place London W1V 0BQ, UK	Aeronaut. Quart.
AIAA JOURNAL American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	AIAA J.
AMERICAN SOCIETY OF CIVIL ENGINEERS, PROCEEDINGS Publications Office, ASCE United Engineering Center 345 East 47th St. New York, NY 10017	
JOURNAL OF ENGINEERING MECHANICS DIVISION	ASCE J., Engr. Mech. Div.
JOURNAL OF ENVIRONMENTAL ENGINEERING DIVISION	ASCE J., Environ. Engr. Div.
JOURNAL OF GEOTECHNICAL ENGINEERING DIVISION	ASCE J., Geotech. Engr. Div.
JOURNAL OF HYDRAULICS DIVISION	ASCE J., Hydraulics Div.
JOURNAL OF IRRIGATION AND DRAINAGE DIVISION	ASCE J., Irrigation Drainage Div.
JOURNAL OF STRUCTURAL DIVISION	ASCE J., Struc. Div.
JOURNAL OF TRANSPORTATION ENGINEERING DIVISION	ASCE J., Transport. Engr. Div.
AMERICAN SOCIETY OF LUBRICATING ENGINEERS, TRANSACTIONS Academic Press 111 Fifth Ave. New York, NY 10019	ASLE, Trans.
AMERICAN SOCIETY OF MECHANICAL ENGINEERS, TRANSACTIONS United Engineering Center 345 East 47th St. New York, NY 10017	
JOURNAL OF APPLIED MECHANICS	J. Appl. Mech., Trans. ASME
JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT AND CONTROL	J. Dyn. Syst., Meas. and Control, Trans. ASME
JOURNAL OF ENGINEERING FOR INDUSTRY	J. Engr. Indus. Trans. ASME
JOURNAL OF ENGINEERING FOR POWER	J. Engr. Power, Trans. ASME
JOURNAL OF LUBRICATION TECHNOLOGY	J. Lubric. Tech. Trans. ASME
APPLIED ACOUSTICS Applied Science Publishers, Ltd. Ripple Road, Barking Essex, UK	Appl. Acoust.
APPLIED MATHEMATICAL MODELING IPC House 32 High St., Guildford Surrey GU1 3EW, UK	Appl. Math. Modeling
ARCHIVE FOR RATIONAL MECHANICS AND ANALYSIS Springer-Verlag, New York, Inc. 175 Fifth Ave. New York, NY 10010	Arch. Rational Mech. Anal.
ARCHIVES OF MECHANICS (ARCHIWUM MECHANIKI STOSOWANEJ) Export and Import Enterprise Ruch UL, Wronia 23, Warsaw, Poland	Arch. Mech. Stosowanej
ASTRONAUTICS AND AERONAUTICS AIAA EDP 1290 Avenue of the Americas New York, NY 10019	Astronaut. & Aeronaut.
AUTOMOBILTECHNISCHE ZEITSCHRIFT Franckh'sche Verlagshandlung Abteilung Technik 7000 Stuttgart 1, Pfizerstrasse 5-7 W. Germany	Automo-biltech. Z.
AUTOMOTIVE ENGINEER P. O. Box 24, Northgate Ave. Bury St., Edmunds Suffolk IP32 GBW, UK	Auto. Engr.
BALL BEARING JOURNAL (English Edition) SKF (U.K.) Ltd. Luton, Bedfordshire LU3 1JF, UK	Ball Bearing J.

PUBLICATION AND ADDRESS	ABBREVIATION
BAUINGENIEUR S. Hirtzel Verlag, Postfach 347 D-700 Stuttgart 1, W. Germany	Bauingenieur
BROWN BOVERI REVIEW Brown Boveri and Co., Ltd. CH-5401, Baden, Switzerland	Brown Boveri Rev.
BULLETIN DE L'ACADEMIE POLONAISE DES SCIENCES, SERIES DES SCIENCES TECHNIQUES Ars Polona-Ruch 7 Krokowskie Przedmiescie, Poland	Bull. Acad. Polon. Sci., Ser. Sci. Tech.
BULLETIN OF THE FACULTY OF ENGINEERING, YOKAHAMA NATIONAL UNIVERSITY Yokahama National University OHKA-MACHI, Minami-ku Yokahama, Japan	Bull. Fac. Eng. Yokahama Natl. Univ.
BULLETIN OF JAPAN SOCIETY OF MECHANICAL ENGINEERS Japan Society of Mechanical Engineers Sanshin Hokusei Bldg. H-9 Yoyogi 2-chome Shibuya-ku Tokyo 151, Japan	Bull. JSME
BULLETIN OF SEISMOLOGICAL SOCIETY OF AMERICA Bruce A. Bolt Box 826 Berkeley, CA 94705	Bull. Seismol. Soc. Amer.
CHEMICAL PROCESSING Putnam Publishing Co. 430 N. Michigan Ave. Chicago, IL 60611	Chem. Processing
CIVIL ENGINEERING (NEW YORK) ASCE Publications Office 345 E. 47th St. New York, NY 10017	Civ. Engr. (N.Y.)
CLOSED LOOP MTS Systems Corp. P. O. Box 24012 Minneapolis, MN 55424	Closed Loop
COMPUTERS AND STRUCTURES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Computers Struc.
DESIGN NEWS Cahners Publishing Co., Inc. 221 Columbus Ave. Boston, MA 02116	Des. News
DIESEL AND GAS TURBINE PROGRESS Diesel Engines, Inc. P. O. Box 7406 Milwaukee, WI 53213	Diesel Gas Turbine Prog.
ENGINEERING MATERIALS AND DESIGN IPC Industrial Press Ltd. 33-40 Bowling Green Lane London EC1R, UK	Engr. Matl. Des.

PUBLICATION AND ADDRESS	ABBREVIATION
EXPERIMENTAL MECHANICS Society for Experimental Stress Analysis 21 Bridge Sq., P. O. Box 277 Westport, CT 06880	Exptl. Mech.
FORSCHUNG IM INGENIEURWESEN Verein Deutscher Ingenieur, GmbH Postfach 1139, Graf-Recke Str. 84 4 Duesseldorf 1, W. Germany	Forsch. Ingenieurw.
HEATING/PIPING/AIR CONDITIONING Circulation Dept. 614 Superior Ave. West Cleveland, OH 44113	Heating/ Piping/ Air Cond.
HIGH-SPEED GROUND TRANSPORTATION JOURNAL Planning Transportation Assoc., Inc. P. O. Box 4824, Duke Station Durham, NC 27706	High-Speed Ground Transp. J.
HYDROCARBON PROCESSING Gulf Publishing Co. Box 2608 Houston, TX 77001	Hydrocarbon Processing
HYDRAULICS AND PNEUMATICS Penton/IPC, Inc. 614 Superior Ave., West Cleveland, OH 44113	Hydraulics & Pneumatics
IBM JOURNAL OF RESEARCH AND DEVELOPMENT International Business Machines Corp. Armonk, NY 10504	IBM J. Res. Dev.
INDUSTRIAL RESEARCH Dun-Donnelley Publishing Corp. 222 S. Riverside Plaza Chicago, IL 60606	Indus. Res.
INGENIEUR-ARCHIV Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Ing. Arch.
INSTITUTION OF MECHANICAL ENGINEERS, (LONDON), PROCEEDINGS Institution of Mechanical Engineers 1 Birdcage Walk, Westminister, London SW1, UK	Instn. Mech. Engr. Proc.
INSTRUMENT SOCIETY OF AMERICA, TRANSACTIONS Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222	ISA Trans.
INTERNATIONAL JOURNAL OF CONTROL Taylor and Francis Ltd. 10-14 Macklin St. London WC2B 5NF, UK	Intl. J. Control
INTERNATIONAL JOURNAL OF EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS John Wiley and Sons, Ltd. 650 Third Ave. New York, NY 10016	Intl. J. Earthquake Engr. Struc. Dynam.

PUBLICATION AND ADDRESS	ABBREVIATION
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Engr. Sci.
INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH Pergamon Press, Inc. Maxwell House, Fairveiw Park Elmsford, NY 10523	Intl. J. Mach. Tool Des. Res.
INTERNATIONAL JOURNAL OF MECHANICAL SCIENCES Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mech. Sci.
INTERNATIONAL JOURNAL OF NONLINEAR MECHANICS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Nonlin. Mech.
INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING John Wiley and Sons, Ltd. 605 Third Ave. New York, NY 10016	Intl. J. Numer. Methods Engr.
INTERNATIONAL JOURNAL FOR NUMERICAL AND ANALYTICAL METHODS IN GEOMECHANICS John Wiley and Sons, Ltd. Baffins Lane Chichester, Sussex, UK	Intl. J. Numer. Anal. Methods Geomech.
INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Solids Struc.
ISRAEL JOURNAL OF TECHNOLOGY Weizmann Science Press of Israel Box 801 Jerusalem, Israel	Israel J. Tech.
JOURNAL DE MÉCANIQUE Gauthier-Villars 55 Quai des Grands Augustines, Paris 6, France	J. de Mécanique
JOURNAL DE MÉCANIQUE APPLIQUÉE Gauthier-Villars 55 Quai des Grands Augustines, Paris 6, France	J. de Mécanique Appl.
JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA American Institute of Physics 335 E. 45th St. New York, NY 10010	J. Acoust. Soc. Amer.
JOURNAL OF AIRCRAFT American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Aircraft

PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF THE AMERICAN HELICOPTER SOCIETY American Helicopter Society, Inc. 30 E. 42nd St. New York, NY 10017	J. Amer. Helicopter Soc.
JOURNAL OF COMPOSITE MATERIALS Technomic Publishing Co., Inc. 750 Summers St. Stamford, CT 06901	J. Composite Matl.
JOURNAL OF ENGINEERING MATHEMATICS Academic Press 198 Ash Street Reading, MA 01867	J. Engr. Math.
JOURNAL OF ENVIRONMENTAL SCIENCES Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	J. Environ. Sci.
JOURNAL OF FLUID MECHANICS Cambridge University Press 32 East 57th St. New York, NY 10022	J. Fluid Mech.
JOURNAL OF THE FRANKLIN INSTITUTE Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Franklin Inst.
JOURNAL OF THE INSTITUTE OF ENGINEERS, AUSTRALIA Science House, 157 Gloucter Sydney, Australia 2000	J. Inst. Engr., Australia
JOURNAL OF MECHANICAL ENGINEERING SCIENCE Institution of Mechanical Engineers 1 Birdcage Walk, Westminister London SW1 H9, UK	J. Mech. Engr. Sci.
JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Mech. Phys. Solids
JOURNAL OF PHYSICS E. (SCIENTIFIC INSTRUMENTS) American Institute of Physics 335 East 45th St. New York, NY 10017	J. Phys. E. (Sci. Instr.)
JOURNAL OF SHIP RESEARCH Society of Naval Architects and Marine Engineers 20th and Northhampton Sts. Easton, PA 18042	J. Ship Res.
JOURNAL OF SOUND AND VIBRATION Academic Press 111 Fifth Ave. New York, NY 10019	J. Sound Vib.

PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF SPACECRAFT AND ROCKETS American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Spacecraft Rockets
JOURNAL OF TESTING AND EVALUATION (ASTM) American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103	J. Test Eval.
KONSTRUKTION Springer Verlag 3133 Connecticut Ave., N.W. Suite 712 Washington, D.C. 20008	Konstruktion
LUBRICATION ENGINEERING American Society of Lubrication Engineers 838 Busse Highway Park Ridge, IL 60068	Lubric. Engr.
MACHINE DESIGN Penton Publishing Co. Penton Bldg. Cleveland, OH 44113	Mach. Des.
MASCHINENBAUTECHNIK VEB Verlag Technik Oranienburger Str. 13/14 102 Berlin, E. Germany	Maschinenbautechnik
MECCANICA Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Meccanica
MECHANICAL ENGINEERING American Society of Mechanical Engineers 345 E. 45th St. New York, NY 10017	Mech. Engr.
MECHANICAL ENGINEERING, TRANSACTIONS, THE INSTITUTION OF ENGINEERS, AUSTRALIA The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600	Instn. Mech. Engr., Australia, Mech. Engr. Trans.
MECHANICS RESEARCH AND COMMUNICATIONS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Res. Comm.
MECHANISM AND MACHINE THEORY Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Mach. Theory
MEMOIRES OF THE FACULTY OF ENGINEERING, KYOTO UNIVERSITY Kyoto University Kyoto, Japan	Mem. Fac. Engr. Kyoto Univ.
MEMOIRES OF THE FACULTY OF ENGINEERING, NAGOYA UNIVERSITY Library, Nagoya University Furo-Cho, Chikusa-ku Nagoya, Japan	Mem. Fac. Engr. Nagoya Univ.
MTZ MOTORTECHNISCHE ZEITSCHRIFT Frankh'sche Verlagshandlung Pfizerstrasse 5-7 7000 Stuttgart 1, W. Germany	MTZ Motortech. Z.
NAVAL ENGINEERS JOURNAL American Society of Naval Engineers, Inc. Suite 507, Continental Bldg. 1012 - 14th St., N.W. Washington, D.C. 20005	Naval Engr. J.
NOISE CONTROL VIBRATION ISOLATION Trade and Technical Press Ltd. Crown House, Morden Surrey SM4 5EW, UK	Noise Control Vib. Isolation
NOISE CONTROL ENGINEERING P. O. Box 2167 Morristown, NJ 07960	Noise Control Engr.
NORTHEAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS, TRANSACTIONS Bolbec Hall, Newcastle Upon Tyne 1, UK	NE Coast Instn. Engrs. Shipbldrs., Trans.
NUCLEAR ENGINEERING AND DESIGN North Holland Publishing Co. P. O. Box 3489 Amsterdam, The Netherlands	Nucl. Engr. Des.
OIL AND GAS JOURNAL The Petroleum Publishing Co. 211 S. Cheyenne Tulsa, OK 74101	Oil Gas J.
OSAKA UNIVERSITY, TECHNICAL REPORTS Faculty of Technology Osaka University Miyakojima, Osaka, Japan	Osaka Univ., Tech. Rept.
PACKAGE ENGINEERING 5 S. Wabash Ave. Chicago, IL 60603	Package Engr.
PHYSICS TODAY American Institute of Physics, Inc. 335 East 45th St. New York, NY 10017	Physics Today
POWER P. O. Box 521 Hightston, NJ 08520	Power
POWER TRANSMISSION DESIGN Industrial Publishing Co. Division of Pittway Corp. 812 Huron Rd. Cleveland, OH 44113	Power Transm. Des.
PRODUCT ENGINEERING (NEW YORK) McGraw-Hill Book Co. P. O. Box 1622 New York, NY	Product Engr. (NY)
QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS Wm. Dawson & Sons, Ltd. Cannon House Folkestone, Kent, UK	Quart. J. Mech. Appl. Math.

PUBLICATION AND ADDRESS	ABBREVIATION
REVUE ROUMAINE DES SCIENCES TECHNIQUES, SERIE DE MÉCANIQUE APPLIQUEE Editions De L'Academie De La Republique Socialiste de Roumanie 3 Bis Str., Gutenberg, Bucurest, Romania	Rev. Roumaine Sci. Tech., Mécanique
REVIEW OF SCIENTIFIC INSTRUMENTS American Institute of Physics 335 East 45th St. New York, NY 10017	Rev. Scientific Instr.
SAE PREPRINTS Society of Automotive Engineers Two Pennsylvania Plaza New York, NY 10001	SAE Prepr.
SIAM JOURNAL ON APPLIED MATHEMATICS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Appl. Math.
SIAM JOURNAL ON NUMERICAL ANALYSIS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Numer. Anal.
SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, NEW YORK, TRANSACTIONS Society of Naval Architects and Engineers 20th and Northhampton St. Easton, PA 18042	Soc. Naval Arch. Mar. Engr., Trans.
S/V, SOUND AND VIBRATION Acoustic Publications, Inc. 27101 E. Oviat Rd. Bay Village, OH 44140	S/V, Sound Vib.
TECHNISCHES MESSEN - ATM R. Oldenburg Verlag GmbH Rosenheimer Str. 145 8 München 80, W. Germany	Techn. Messen

PUBLICATION AND ADDRESS	ABBREVIATION
TRANSACTIONS OF THE INSTRUMENT SOCIETY OF AMERICA Instrument Society of America 400 Standix St. Pittsburgh, PA 15222	Trans. Instr. Soc. Amer.
TURBOMACHINERY INTERNATIONAL Turbomachinery Publications, Inc. 22 South Smith St. Norwalk, CT 06855	Turbomach. Intl.
VDI ZEITSCHRIFT Verein Deutscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Duesseldorf 1, Germany	VDI Z.
VEHICLE SYSTEMS DYNAMICS Swets and Zeitlinger N.V. 347 B. Herreweg Lisse, The Netherlands	Vehicle Syst. Dyn.
VIBROTECHNIKA Kauno Polytechnikos Institutas Kaunas, Lithuania	Vibrotechnika
WEAR Elsevier Sequoia S.A. P. O. Box 851 1001 Lausanne 1, Switzerland	Wear
ZEITSCHRIFT FÜR ANGEWANDTE MATHEMATIK UND MECHANIK Akademie Verlag GmbH Liepziger Str. 3-4 108 Berlin, Germany	Z. angew. Math. Mech.
ZEITSCHRIFT FÜR FLUGWISSENSCHAFTEN DFVLR D-3300 Braunschweig Flughafen, Postfach 3267 W. Germany	Z. Flugwiss

ANNUAL PROCEEDINGS SCANNED

INTERNATIONAL CONGRESS ON ACOUSTICS, ANNUAL PROCEEDINGS	Intl. Cong. Acoust., Proc.
INSTITUTE OF ENVIRONMENTAL SCIENCES, ANNUAL PROCEEDINGS Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	Inst. Environ. Sci., Proc.
MIDWESTERN CONFERENCE ON SOLID MECHANICS, ANNUAL PROCEEDINGS	Midw. Conf. Solid Mech. Proc.
THE SHOCK AND VIBRATION BULLETIN, UNITED STATES NAVAL RESEARCH LABORATORIES, ANNUAL PROCEEDINGS Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375	Shock Vib. Bull., U.S. Naval Res. Lab., Proc.
UNITED STATES CONGRESS ON APPLIED MECHANICS, ANNUAL PROCEEDINGS	U.S. Cong. Appl. Mech., Proc.
WORLD CONGRESS ON APPLIED MECHANICS, ANNUAL PROCEEDINGS	World Cong. Appl. Mech., Proc.

CALENDAR

JUNE 1978

19-23 **International Conference on Fundamentals of Tribology,** [U.S. Army Research Office] MIT, Cambridge, MA *(Prof. Nam P. Suh, Dept. of Mech. Engrg., MIT, Cambridge, MA 02139 - Tele. (617) 253-2225)*

30 **Eighth U. S. Congress of Applied Mechanics,** [ASME] Los Angeles, CA *(ASME Hq.)*

SEPTEMBER 1978

11-13 **IUTAM Symposium on Variational Methods in the Mechanics of Solids,** [U.S. Army Research Office & National Science Foundation & Northwestern University] Evanston, IL *(Prof. S. Nemat-Nasser, Dept. of Civil Engrg., Northwestern Univ., Evanston, IL 60201 - Tel. (312) 492-5513.)*

24-27 **Design Engineering Technical Conference,** [ASME] Minneapolis, MN *(ASME Hq.)*

OCTOBER 1978

8-11 **Diesel and Gas Engine Power Conference and Exhibit,** [ASME] Houston, TX *(ASME Hq.)*

8-11 **Petroleum Mechanical Engineering Conference,** [ASME] Houston, TX *(ASME Hq.)*

17-19 **49th Shock and Vibration Symposium,** [U.S. Naval Research Lab.] Washington, D.C. *(H. C. Pusey, Director, The Shock and Vibration Info. Ctr., Code 8404, Naval Res. Lab., Washington, D.C. 20375 - Tel. (202) 767-3306)*

17-19 **Joint Lubrication Conference,** [ASME] Minneapolis, MN *(ASME Hq.)*

NOVEMBER 1978

26 - Dec 1 **Acoustical Society of America, Fall Meeting,** [ASA] Honolulu, Hawaii *(ASA Hq.)*

DECEMBER 1978

4 - 6 **15th Annual Meeting of the Society of Engineering Science, Inc.,** [SES] Gainesville, FL *(Prof. R. L. Sierakowski, Div. of Continuing Education, Univ. of Florida, 2012 W. University Ave., Gainesville, FL 32603)*

10-15 **Winter Annual Meeting,** [ASME] San Francisco, CA *(ASME Hq.)*

JUNE 1979

11-15 **Acoustical Society of America, Spring Meeting,** [ASA] Cambridge, MA *(ASA Hq.)*

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS:	American Federation of Information Processing Societies 210 Summit Ave., Montvale, NJ 07645
AGMA:	American Gear Manufacturers Association 1330 Mass. Ave., N.W. Washington, D.C.
AHS:	American Helicopter Society 1325 18 St. N.W. Washington, D.C. 20036
AIAA:	American Institute of Aeronautics and Astronautics, 1290 Sixth Ave. New York, NY 10019
AIChE:	American Institute of Chemical Engineers 345 E. 47th St. New York, NY 10017
AREA:	American Railway Engineering Association 59 E. Van Buren St. Chicago, IL 60605
AHS:	American Helicopter Society 30 E. 42nd St. New York, NY 10017
ARPA:	Advanced Research Projects Agency
ASA:	Acoustical Society of America 335 E. 45th St. New York, NY 10017
ASCE:	American Society of Civil Engineers 345 E. 45th St. New York, NY 10017
ASME:	American Society of Mechanical Engineers 345 E. 47th St. New York, NY 10017
ASNT:	American Society for Nondestructive Testing 914 Chicago Ave. Evanston, IL 60202
ASQC:	American Society for Quality Control 161 W. Wisconsin Ave. Milwaukee, WI 53203
ASTM:	American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103
CCCAM:	Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada
ICF:	International Congress on Fracture Tohoku Univ. Sendai, Japan
IEEE:	Institute of Electrical and Electronics Engineers 345 E. 47th St. New York, NY 10017
IES:	Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056
IFToMM:	International Federation for Theory of Machines and Mechanisms, US Council for TMM, c/o Univ. Mass., Dept. ME Amherst, MA 01002
INCE:	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch Poughkeepsie, NY 12603
ISA:	Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222
ONR:	Office of Naval Research Code 40084, Dept. Navy Arlington, VA 22217
SAE:	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, PA 15096
SEE:	Society of Environmental Engineers 6 Conduit St. London W1R 9TG, UK
SESA:	Society for Experimental Stress Analysis 21 Bridge Sq. Westport, CT 06880
SNAME:	Society of Naval Architects and Marine Engineers, 74 Trinity Pl. New York, NY 10006
SPE:	Society of Petroleum Engineers 6200 N. Central Expressway Dallas, TX 75206
SVIC:	Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375
URSI-USNC:	International Union of Radio Science - US National Committee c/o MIT Lincoln Lab., Lexington, MA 02173

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